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Integration of Color Equipment in a Television Station

By PHILLIP B. LAESER

WTMJ-TV's pioneer color installation and the operational problems faced by its engineers during 1954 and early 1955 are discussed. The results and experience gained by integrating color film slides and live color camera equipment with the monochrome system are given. The scope of the discussion includes some of the technical difficulties and handling of the color signals from the camera to studio control room through the master and TV transmitter. Color test procedures, lighting, air-conditioning and manpower requirements are explained.

On July 18, 1954, WTMJ-TV presented local color television to Milwaukee by producing a one-hour variety show, called the Grenadiers. Since that date we have been airing color shows with increased regularity. We received our 2 × 2 slide camera during April and in May the live color camera arrived. Both of these units were ready for use by July 1. The next few weeks were an experimental period during which the production and programming personnel were given an opportunity to get the feel of color. Meanwhile the engineering group was working around the clock on training its personnel to work with color. During 1954 WTMJ-TV presented from its color studio 41 programs totaling 18 hr. NBC supplied us during 1954 with 56 hr. Based on our accelerated plan inaugurated January 1, we expect to produce from Milwaukee's Radio City over 300 different color shows totaling about 150 hr. This represents an average of a 30-min show a day. NBC is expected to provide us with 200 hr of full color this year.

During the initial planning, many possible equipment arrangements were investigated. The decision was made to use one of our larger studios for both monochrome and color operations. Fortunately the D control room which is located on the second floor level had adequate space for the installation of additional equipment. In converting Studio D for color we allowed for the fact that we still wanted to use it a large percentage of the time for monochrome shows. Thus all of the outlets for monochrome cameras were left in place in the studio. We planned to have color equipment to air every type of program material. What we wanted was one type of everything that would be needed for full color operation but without extras to gather dust and become obsolete.

With this in mind our station was equipped as follows: (1) complete network color equipment; (2) color syncronizing equipment; (3) color test units; (4) color slide equipment; (5) live color camera; and (6) a color film chain.

The monochrome equipment in the control room was rearranged and the color gear carefully fitted in to provide an integrated operation. As shown in Fig. 1, the camera control consoles for the monochrome equipment were placed near the studio window next to the switcher which had been modified to accept the color signals. Directly to the right of the switcher is the color camera control unit. The entire video console is formed in an L shape. Around the corner is the control console for the color slide unit. Further along is placed the color film control, multiplexer and the 16mm projector. Directly over and to the rear of the monochrome and color camera control units are located three color monitors. In this position each of these monitors can be viewed by the entire operating and production personnel in the control room. To the left is the black-and-white film preview monitor, second is a color line monitor, next is the color live camera monitor and last is the color film monitor. A switch is inserted in the video line to flip this monitor to the 2 × 2 slide unit if necessary. Note that the "on the air" color monitor is used for both color and black-and-white.

Directly back of the operating consoles are located 13 racks of associated equipment (Fig. 2). The first rack houses the sync generator; second rack, pulse distribution; the third and fourth house the color test gear; the fifth, sixth, seventh and eighth racks hold the colorplexers, channel amplifiers, gamma amplifiers and aperture compensators. Several blank racks are provided for additional future color chains. The last two racks house the monochrome and the audio equipment. All of the power supplies are mounted in 12 open racks in an adjacent power supply room. This room is provided with exhaust ventilation in order to hold the temperature of the equipment within limits. About 5000 cfm of air is circulated to the roof. Note that several racks contain voltage regulator units which feed the filaments of the critical color circuits. We have found that these regulators have stabilized our color operations immeasurably. Directly adjacent to the control room and the power supply room is located a small shop area used for maintenance and test purposes.

We are presently using one live color camera. It is surprising what can be done with one camera. Of course it is impossible to produce an extravaganza or a large dramatic show but such shows are seldom done locally. The programs which most independent stations produce very well are usually small musical groups, interviews, kitchen shows, fashion shows, news and weather. It should be understood that engineering, production and program people must use a little ingenuity in order to progress smoothly from one scene to another.

We developed a technique that worked very well by planning the action and sets with single-camera continuity in mind. It also requires using increased movement by the participating talent since that tends to make up for the lack of several cameras. At home the viewers seldom distinguish these one-camera

Presented on April 20, 1955, at the Society's Convention at Chicago, by Phillip B. Laeser, Radio and TV Engineering, WTMJ-TV–WTMJ, The Milwaukee Journal, Milwaukee 1, Wis.

(This paper was received on August 10, 1955.)



Fig. 1. Color and monochrome TV control equipment in the WTMJ-TV Studio D control room. Top row of monitor, left to right: monochrome film preview, color "off the air," live camera, color film camera, lower two black-and-white camera controls, line switcher, color camera control and monitor. Around corner is the 2 × 2 color flying-spot control and monitor and the control position for 3-V film unit. To the rear is visible the door leading into the power room housing 12 racks of power supplies. Right rear are shown several of 13 racks of associated control and test equipment.

shows from a two-camera pickup. We have helped ourselves considerably by devising a mounting on our color camera for the Electrazoom lens which has been used very successfully on many of our shows. This lens allows the cameraman to zoom in on parts of the set without moving his heavy and bulky camera. The Electrazoom does introduce certain limitations. Because its widest angle is 26°, it has to be at least 30 ft back in order to take a 15-ft set. The length of the color camera and the Electrazoom added to that required by the cameraman adds up to 38 ft as a necessary minimum. In some studios getting the camera far enough back will be a problem. For this reason, we prefer to use the lens on either of the long ends of the studio. Our studio is 32 × 56 × 26 ft. Incidentally, extremely tall cameramen are usually assigned because on a color camera the taking lens is on the bottom of the turret. When table top sheets are required, the camera pedestal is usually raised so high that it is difficult for a shorter cameraman to look into the viewfinder. Because of this we have developed a mirror assembly which attaches to the front of the camera. This mirror assembly in effect raises the camera shots by about 16 in. We find that this mirror assembly which is shown in Fig. 3 can provide shots that are unattainable by using the normal lens assembly.

We at WTMJ-TV have found that more time is required for setup in color. There are several reasons for this. One is that the equipment takes longer to warm up. The second is that the camera check-out takes longer. A third reason is that light for color is more critical and time must be allowed to set it properly. The exact time for these operations is difficult to state accurately because sometimes they are sandwiched in with other control room jobs. Equipment warm-up is usually going on while other maintenance work is in progress. Camera check-up is done before and between rehearsals and lighting check-out periods. The following is a typical schedule:

Rehearsal time minus 2 hr—camera warm-up by maintenance crew or camera control man. During this period the man turns on sync generator, checks out rack equipment using the color bar generator.

Rehearsal time minus 1 hr—camera check-out by the cameraman and the camera control man. During this period the technical supervisor works with the production department in the studio on the lighting and the technical requirements of the show. He will also preview all color slides and any film that may be used on the show.

Show time minus 15 min—the final camera check-out is done *after* the rehearsal time is completed and just previous to the show's hitting the air. During this time the crew has an opportunity to check the camera on the following test charts: registration, cross gamma, linearity and a color chart. In the control room a last-minute check is made on the colorplexers using the color bars and the Vectorscope. During this 15 min the crew usually finds time for a break of a few minutes.

The technical crew on a show includes one man on each of the following positions: color camera, mike boom, video control and audio. A technical supervisor is on duty to coordinate its requirements with the production staff. Switching is done by the video engineer as directed by the program director. The same size technical crew is used with the exception that only one camera is used for color compared to two for mono-

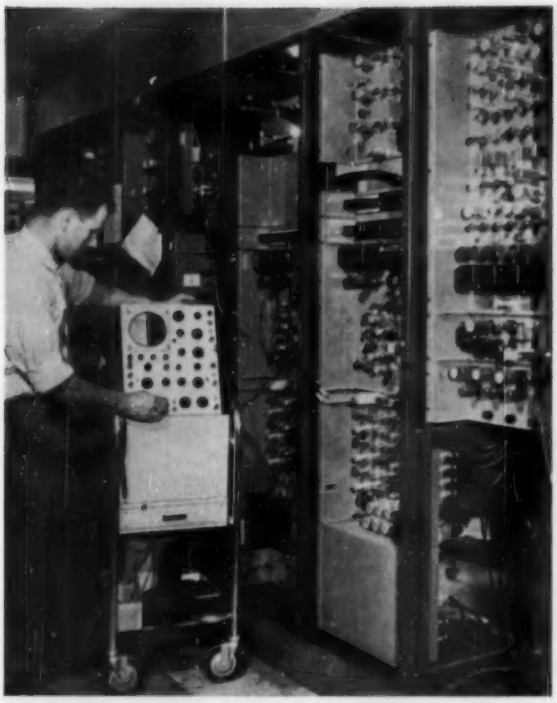


Fig. 2. Equipment racks, not including power supplies.

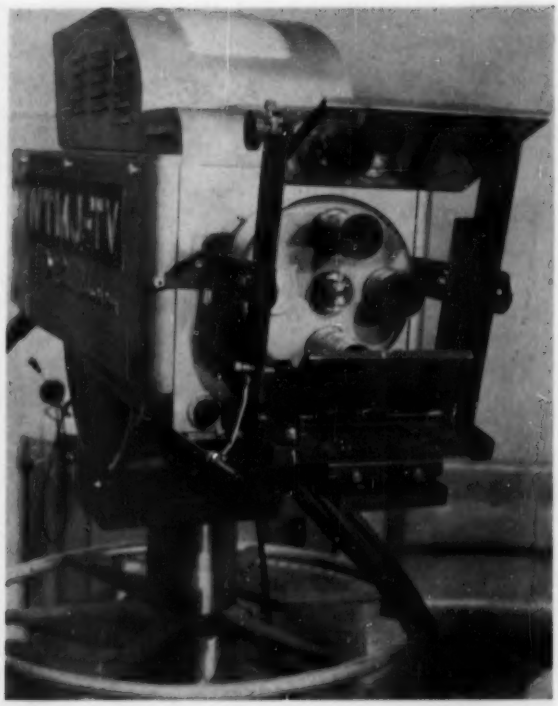


Fig. 3. WTMJ-TV Periscope assembly mounted on color camera. Mirror control to allow straight-through shot from the lower 135-mm lens is also shown. This assembly allows camera views from a much higher angle than previously available.

chrome. During a color show that requires color film inserts, an additional man is scheduled to handle the film video control position.

At WTMJ-TV we have a convenient way of using the background projection unit. On one side of our Studio D there is a large door opening into a corridor. By using this space for the projector unit with the screen set in the studio doorway, very little studio space is required. This background projection unit is frequently used on our monochrome shows. Recently we inaugurated a color show which required a Pledge of Allegiance to our Flag. We found very good use for the rear-projection screen by using the American Flag set about two feet in front of the screen. The lighting on the flag consisted of a 750-w spot (approximately 75 ft-c). The scene on the blue latex screen consisted of a cloud formation using a monochrome 4 × 5 slide. The effect on the air, using an electric fan to ruffle the flag, was excellent. After this many other background effects were soon suggested using monochrome slides for future color shows.

In addition to using our Studio D for color, we have tried out live color in other areas. For example we have used it in the kitchen studio. Currently we are producing in color every fifth week, for the entire week, a daily kitchen show. Directly west of our studio building is the oudoor studio which has been very popular for monochrome shows. During the spring, summer and fall it is used almost every day. The outdoor studio is equipped with two manholes each containing the necessary camera, microphone and intercom cables. Asphalt runways lead from the side door to several sections of the studio. These include the reflecting pool, garden plot, etc. At the present time we are experimenting with the results obtained by using color originating in this area. By next fall we will have many more answers to the use of an outdoor studio.

During the color planning, it was immediately apparent that a number of changes would be required in the television lighting. Our monochrome lighting facilities basically provided for about 100 ft-c. Originally this lighting was part fluorescent and part incandescent. The fluorescent fixtures were removed and additional outlets were installed on the overhead grid (Fig. 4). We now have 56 grid outlets and an additional 32 outlets around the wall and on the catwalk. We use 25 pantagraphs mounted in 7 rows across the width of the studio. Each pantagraph has a horizontal bar at the lower end to which are attached the various scoops or spots. In addition there is a pipe rail around the studio, attached to this rail are 40 750-w spots. These spots are mainly used for backlighting. We also have numerous portable floor lamps which are used for key-lighting purposes. In order to facilitate the handling of the number of studio lights, we have installed a Rotolector and dimmer board. The total capacity for studio lighting is 600 amp.

The light arrangement for color was originally planned to light two or three color sets at a time, one at each end of the studio and one across the narrow side of the studio. We provided for 400-ft-c base light. We have found that under controlled conditions very excellent color can be produced with light levels of 250 ft-c. Generally speaking 300 ft-c is a more realistic figure. The lighting is checked out by the technical supervisor and the floor director just prior to and during the rehearsal time. The usual monochrome floor monitor is not used by the crew in the studio to set the lights. The effects and the adequacy of the lighting are judged in the control room. Dimming is used very cautiously. We find that the dimmer controls materially reduce the unbalance and hot spots in certain sections of the set. If carried too far the dimmers affect the spectral response of the light and consequently produce undesirable effects in the quality of the color.

Initially plans were made to use RCA's fast pulldown color-film projector and the flying-spot camera. This unit was scheduled for delivery last May. However, after personally watching the prototype of the new 3-Vidicon color film camera, we decided to wait for this new unit. The installation therefore was delayed until last November. Consequently

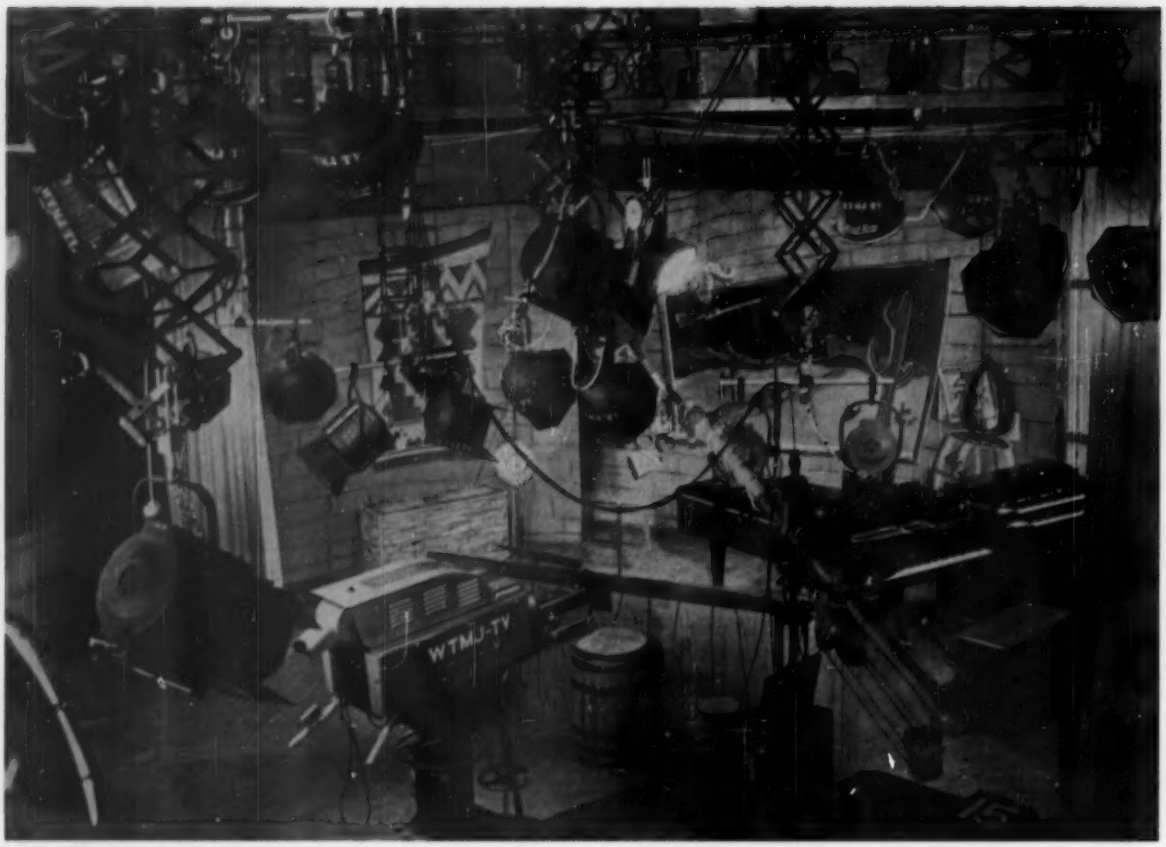


Fig. 4. View of WTMJ-TV Studio D: 1-kw scoops and spots, used for base lighting, are suspended on pantagraphs. Smaller spots, used for back lighting, are attached to pipe battens around three sides of the studio. Color camera with Electrozoom lens and mike boom are also shown.

we have had only five months of experience with this 3-V unit. As a test period, we intentionally installed the film camera, its control equipment and 16mm projector in the color control room (Fig. 5). All phases of our color programming could then be coordinated as one project rather than have the equipment spread over the entire building. Later on when the amount of color film increases, we plan to move the projector and camera control units into the Telecine Room adjacent to the TV master control room. It is at this center of operation that we normally insert all film, commercial spots, titling cards and slides. We will then be able to process either color or monochrome film material without switching or keeping alive another studio area. At the present time the amount of color film suitable for television is very limited. To date we have found the 3-V unit to be very stable and easy to line up.

Practically all of my previous comments have dealt with the production and engineering facilities necessary to produce a color show. Several very important areas of engineering operation are necessary in order to transmit the program over the air. The initial spadework in color television at our station was done at the television transmitter. NBC began feeding us color shows beginning with the Donald O'Connor Show in November 1953. Immediate steps were taken to convert our transmitter so that we could use these color transmissions. The Tournament of Roses from Pasadena and many other color shows soon followed.

The most important sections of the transmitter to be converted were the modulator, filterplexer and the auxiliary video input equipment. The clamping circuit in the modulator unit had to be modified so that it would not interfere with the color burst. This burst is transmitted on the back porch of each horizontal line. The transmitter circuits were checked and lined up to minimize differential phase shift. New elements were installed in the filterplexer. The filterplexer is located in the transmission line between the output of the transmitter and the antenna system. These new elements have reduced the possibility of radiated interference to receivers in the lower adjacent channels from the color burst carrier.

Additional equipment such as the low- and high-frequency phase correction networks and the color stabilizing amplifier and color monitors were installed. It was then possible to take the network feed and pass it directly through our master control room to the transmitter and obtain satisfactory transmission for the many early color demonstrations.

In the first six months a very small amount of satisfactory color test equipment was available. As this equipment arrived it was easier to check out the main video lines from the master control to the transmitter so that color could be achieved on a daily basis. During this initial period the master control was almost completely by-passed so as to minimize any possible detrimental effect on the burst phase or amplitude. However, at the present time the master is used completely for routing network and locally produced color or monochrome shows.

Regular maintenance procedures are carefully followed several times each week during off-the-air periods in order to assure proper operating conditons at the master and transmitter. Color moni-

tors are maintained in each of these positions. Test units particularly useful at the transmitter are the multiburst frequency generator and the stair steps linearity checker. In addition to these units the transmitter also uses the sideband response analyzer necessary to achieve the tighter amplitude vs. frequency tolerances required by the color signal. These units when used with the color signal analyzer indicate when proper differential phase and amplitude tolerances are obtained.

Test units at the studio control room are the color bar generator, multiburst generator, dot generator, Vectorscope, stair steps, color signal analyzer, square wave generator and several wideband oscilloscopes. Each of these units serves a well-defined useful purpose in the color operations. Particularly valuable in our control room is the Vectorscope. The Vectorscope provides a cathode-ray presentation of the phase vs. amplitude characteristics of the operating equipment. It is used during the final checkout time just prior to hitting the air with the color program. A quick check is made with the Vectorscope using the color bars on each of the colorplexers to indicate whether the units are within FCC and NTSC standards. The oscilloscope display shows the color sync burst relative to the angles and the amplitudes of the various colors and the chrominance channels. Plus or minus tolerance limits are clearly indicated on an overlay. Maintenance in itself is a subject wide in scope and unfortunately cannot be covered in detail in this discussion.



Fig. 5. View of the color 3-V 16mm film equipment. Cover has been removed to show each of the three vidicon cameras at the extreme left. Controls are mounted in cabinet below; 2 × 2 automatic slide projector is shown on shelf at right; and audio equipment in racks at rear.

Conclusion

In conclusion the following should be noted: no increase in staff was required by the addition of the color equipment, although some overtime was necessary during the installation period. The installation was performed entirely by the staff on the maintenance time allocated. Initially, in order to maintain high standards of performance, a color engineering corps was formed to handle these specific color assignments. Later on, this group was further expanded using the original corps as a training unit. Experience, gained to date, shows that the three image-orthicon tubes in the color camera should equal or better the tube life compared to similar tubes used in a monochrome camera. During this same period of operating color equipment, it was found that the air-conditioning load was considerably greater than anticipated and necessitated a number of modifications. Only minor building alterations were found necessary by the addition of color equipment.

It is anticipated that as color program hours on the station increase and monochrome decreases, the color film and slide equipment now located in the separate control room will be moved to the master control area to replace the present monochrome units. Color or monochrome signals will then be continuously available from a single unit for this dual use during an entire day's schedule of operations.

On the program and production side, these months of experience proved it better and more efficient to designate a regular pattern of color shows on a weekly or monthly basis rather than piecemeal choosing of local shows suitable for color on an irregular basis.

CBS Television Color Studio 72

By ROBERT B. MONROE

In the fall of 1954, CBS Television inaugurated color television program service from a new modern theater studio in New York City. This studio, known as CBS Television Studio 72, is one of the best equipped television studios in service today, being provided with facilities to originate television programs not only in color but in monochrome as well. It is the purpose of this paper to describe the technical facilities installed in this studio.

CBS Television Studio 72 is located in Manhattan at Broadway and 81st St. It was originally designed and built as a vaudeville theater and, for that reason, was already equipped with many of the facilities necessary in a theater originating large-scale network television productions.

Architectural Considerations

As is well known, many theaters are readily adapted for use as television studios. Theaters usually have the advantage of being located in areas easily accessible to both the performers and the studio audience. In addition, theaters are already equipped with audience seats and other facilities to accommodate the studio audience, the audience being an important and essential part of many television programs. Furthermore, theaters that have served as vaudeville or legitimate theaters are equipped with dressing rooms as well as stage access doors adequate to accommodate the passage of large stage scenery and other stage properties. Needless to say, dressing rooms and large stage access doors are essential elements in a television studio.

An invited contribution submitted on June 6, 1955, by Robert B. Monroe, CBS Television, 485 Madison Ave., New York 22. A condensed presentation of this subject was made at the 1955 Convention of the National Assn. of Radio and Television Broadcasters.

From the viewpoint of conversion to television studio use, the major difficulty with most theaters is the fact that the stage is usually too small. This shortcoming, together with the fact that control rooms, additional lighting equipment, and additional air-conditioning and ventilating facilities must be provided, usually dictates rather extensive modification to a theater to convert it to a television studio. When color television is involved, the lighting and air-conditioning requirements are even greater than when monochrome alone is involved.

When Studio 72 was acquired by CBS Television early in 1954, it was equipped with a very shallow stage providing only 2000 sq ft of stage working area — hopelessly inadequate for the staging and production of present-day television musical and dramatic productions. The theater, as it existed, accommodated an audience of 2000 with 1150 seats in the orchestra and 850 seats in the balcony. It was decided to trade a large portion of the audience area of the orchestra floor to enlarge the stage as well as provide space for control rooms.

Figure 1 shows the ground floor arrangement after the theater was modified for television broadcasting. First, the front 15 rows of seats were removed and the stage built out to provide a 5000 sq ft staging area — two and one half times the original stage size. Then the rear 10 rows of seats were removed, as well as a substantial portion of the inner lobby, to provide space for control rooms and other technical areas. Of the original 32 rows of orchestra seats only 7 rows were left, seating an audience of 300.

The theater was already equipped with six levels of backstage dressing rooms. This dressing room area was expanded and modernized and a wardrobe and make-up room added. The theater was also equipped with a large stage entrance adequate to handle the largest stage sets and properties.

It will be noted that two separate control rooms have been provided in this studio. One is equipped with color equipment, the other with monochrome equipment.

Figure 2 is a plan view showing the mezzanine floor, the lower portion of the balcony, and the upper portion of the staging area. The mezzanine area, directly above the inner lobby, is used for offices, workshop, and power supply room. In the lower portion of the balcony the first three rows of seats were removed and the floor leveled to provide a nine foot wide level working area across the front edge of the entire balcony. This area serves as an off-stage location for the sound-effects station and, when necessary an orchestra. It is also employed for overhead cameras and spotlights. A small group of balcony seats have been equipped with picture monitors and sound reinforcement loudspeakers. This area serves as a convenient location for visitors to view rehearsals or air programs on picture monitors but these balcony seats are not suitable for a direct view of the stage because of the visual obstruction of lighting equipment.

Other Building Modifications

In addition to the major architectural

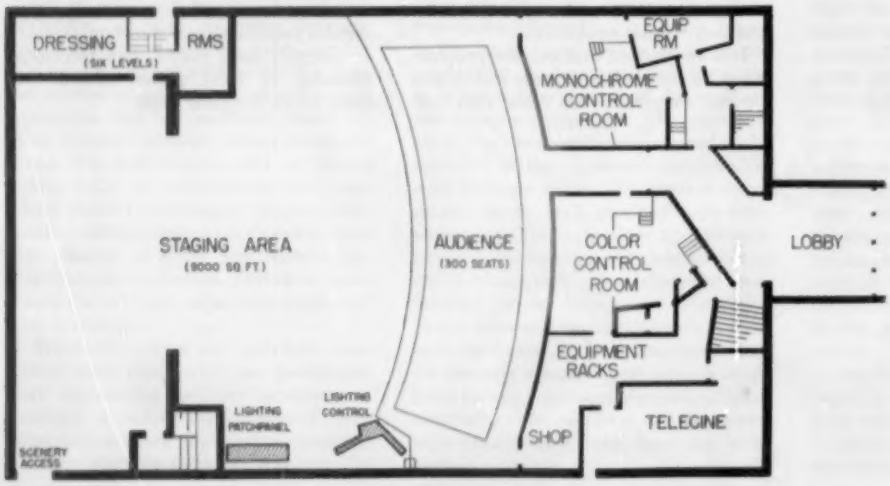


Fig. 1. Plan view of the ground level floor of CBS Television Studio 72. The original proscenium arch, which marked the limit of original stage, can be seen at the left. Should a still larger stage be required, the remaining audience seats can be removed and the stage extended to the control room wall.

modifications described above, the physical and electrical modifications and additions described in the following paragraphs were also required to convert the theater for television studio use.

Primary Power. The capacity of the primary power available when Studio 72 was acquired by CBS Television, although adequate for theater use, was much too small for the heavy power demands of a color television studio; therefore, a new primary power service with a feeder capacity of 2300 kva. 120/208 v, three-phase, was installed. The largest load on this supply is, of course, the stage lighting system which requires as much as 750 kw of power. The audio-video installation requires approximately 200 kw and the air-conditioning and ventilating systems 450 kw. A small amount of additional power is required for general building lighting and power.

Audio-Video Power. Twenty four equipment racks house the 130 regulated power supplies located in the power room on the mezzanine floor which supply d-c power to the audio and video equipment in the entire plant. Approximately 45 amp at 285 v, regulated to considerably better than 0.1% is required.

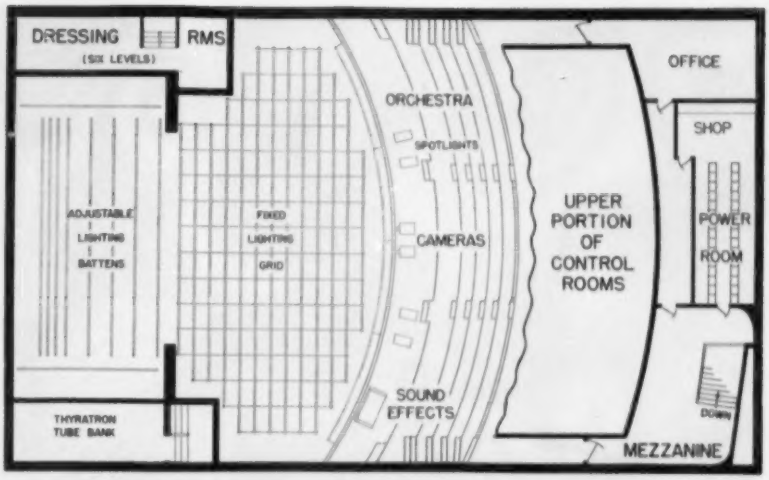


Fig. 2. Plan view of the upper level of CBS Television Studio 72.

In addition to the use of electronically regulated plate power supplies, all a-c power used for the operation of audio and video facilities is regulated through the use of three induction regulators, one on each phase of the a-c power. Therefore, all audio-video a-c power, even that



Fig. 3. The studio from the rear of the stage looking toward the control rooms. The color control room is on the right, the monochrome control room is on the left. The audience seating area can be seen between the stage and control rooms.

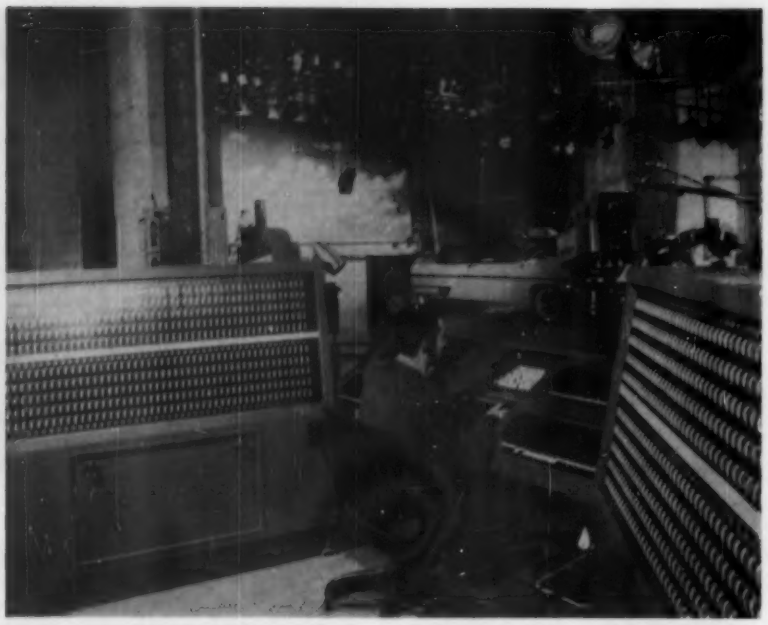


Fig. 4. The electronic control console for lighting Studio 72.

used on the tube heaters, is regulated. This seemingly extreme regulation of power to the video facilities is essential for stable operation at the present state of the color television art. As a matter of fact, such regulation is usually highly desirable in monochrome installations.

Stage Lighting. It is customary to run lighting levels ranging from 300 to 500 ft-c in CBS Television color operations.[1] This level of lighting calls for lighting power in the order of 150 w/sq ft of studio staging area.

The general arrangement of supporting overhead stage lighting fixtures is shown on Fig. 2. Fixtures in the rear portion of the staging area, behind the original proscenium arch, are suspended from eight 1½-in. steel pipe battens. Actually, there are 24 battens above this area of the stage, the remainder being used to support stage backdrops or scenery. All of these pipe battens are adjustable in height from 5 to 50 ft above the stage floor. Wiring to cable type power outlets along each batten is carried in a 4 by 4 in. steel wiring duct mounted directly above the batten. Lighting fixtures suspended from these adjustable battens are easily accessible for adjustment by lowering the batten to a level at which the fixture can be conveniently reached from the studio floor. Supplementary lighting fixtures, when required, can be suspended in this rear area of the stage from fixed battens mounted at right angles to those described above, one at each side of the stage.

Lighting fixtures in the staging area forward of the original proscenium arch are supported from a fixed lighting grid constructed of 1½-in. steel pipe mounted 24 ft above the stage floor. Wiring to the power outlets on this lighting grid is also carried in a 4 by 4 in. steel wiring duct. Catwalks immediately above this lighting grid, accessible from the theater balcony, provide a convenient means of access to lighting fixtures suspended from this grid when adjustment is necessary.

Another long, curved, light-fixture supporting batten is mounted along the forward edge of the balcony 14 ft above the stage floor. Wiring to 32 power outlets along the length of this long batten is carried in a 6 by 6 in. metal wiring duct.

Altogether there are 470 overhead power outlets evenly distributed throughout the stage overhead area. This large distribution of power outlets provides the basis of a very flexible lighting system that is adaptable to the lighting requirements of practically any television program. A large variety of different sizes and types of lighting fixtures is on hand to provide the best lighting arrangement for the particular program using the studio.

Lighting Control. Control of studio lighting is considerably more critical in color than in monochrome operation. Stage lighting at Studio 72 is controlled by the electronic lighting control console shown in Fig. 4. This control console can handle as much as 750 kw of studio incandescent

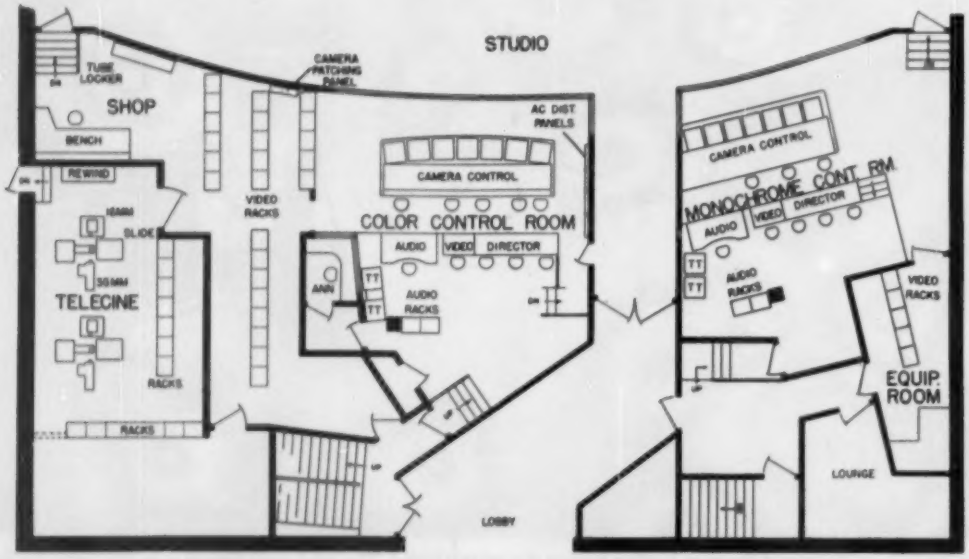


Fig. 5. Plan of the control rooms and associated technical areas.



Fig. 6. This photograph shows the excellent visibility of both the stage and control-room monitors from the director's console. Neutral density shades on the control-room windows, with a transmission of 10%, reduce the brightness of the highly illuminated stage to match the lower brightness of the control-room monitors.

lighting; 500 kw on 100 5-kw dimmer circuits and 250 kw on 50 5-kw nondimmer switch circuits. The lighting console features a built-in electronic memory circuit which permits the immediate return to any one of ten predetermined settings of the 100 dimmer circuits by the operation of a pushbutton selector.

Connection between any lighting fixture and the desired control console dimmer or switch position is established on the lighting patch panel (Fig. 1). The thyratron tube bank is located in a room on the second floor above the left side of the stage as shown on Fig. 2.

Air Conditioning and Ventilating. In view of the large amount of heat produced by the studio lighting equipment, the audio-video facilities, and the studio operating personnel, performers, and audience, a formidable ventilation and air-conditioning system is required.

The air-conditioning system at Studio 72 employs three compressors, one 100 ton, one 75-ton, and one 40-ton. All compressors provide refrigeration for a closed chilled water system and are interconnected so that any one, two or three compressors can be used as the load requires.

The air conditioning system is augmented by six exhaust fans at the ceiling level which serve to exhaust excessive hot air from the overhead area, thereby easing the load on the air-conditioning system.

Acoustical Characteristics. It is usually desirable to employ as much sound absorbing treatment on the walls and ceiling of a television studio as possible to reduce the reverberation time to a low value.[2] This was achieved in CBS Television Studio 72 by the application of highly absorbent acoustical blankets on the walls and overhead surfaces of the staging area of the studio.

Control Room Arrangement

Figure 5 is a plan view of the control rooms and associated areas. The color control room employ the same general equipment arrangement long used in CBS Television monochrome operations.[3] This arrangement is based on the important consideration that it enables all persons concerned with the production of a program to make their observations on the same picture monitors. This consideration is more important than ever in color operation.

Control room personnel are grouped around the program director who sits at the left end of the directors console. The assistant director and other program assistants are at his right and key technical personnel, the video switcher and audio mixer, are at his left. Directly in front of the director, at a lower level, is the camera control console which contains color picture monitors associated with each studio camera and other program sources. The director and other personnel on the upper level of the control room have an unobstructed view of the stage, the control room color monitors and the camera control monochrome monitors as can be seen in Fig. 6.

Twenty four equipment racks in the area to the left of the control room contain pulse generation and distribution equipment, color camera channels, video switching and distribution equipment, and measuring and test equipment.

Immediately adjacent to the rack area of the control room is a small well-

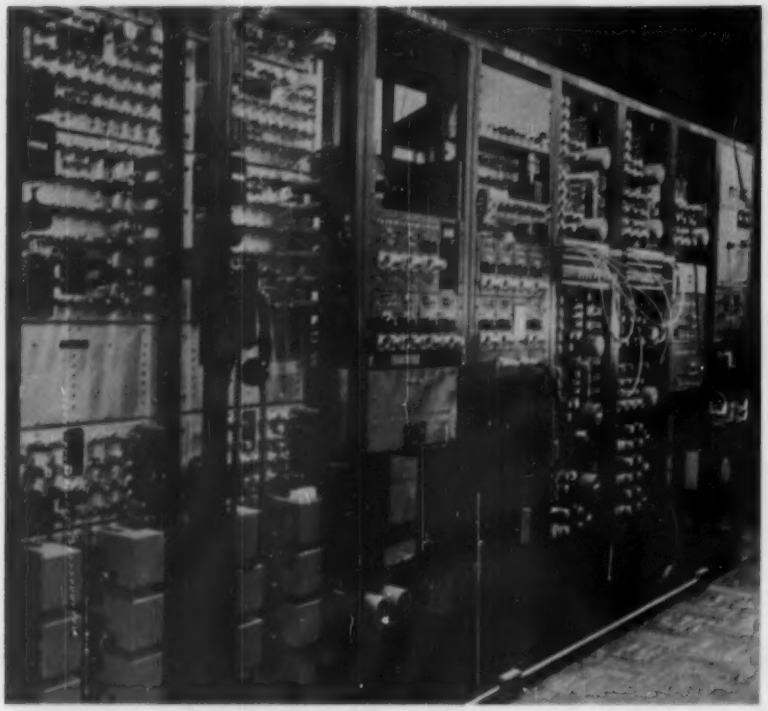


Fig. 7. This bank of equipment racks contains the regular and emergency pulse generators, pulse-distribution units, pulse-distribution amplifiers, and subcarrier frequency measuring equipment. The pulse-distribution units, on the third and fourth racks from the left, provide visual neon-tube monitoring of all pulse and subcarrier signals at each important junction of the pulse-distribution system, access to pulses for oscilloscopic monitoring, and provision for switching to a spare pulse feed should the regular pulse source fail.

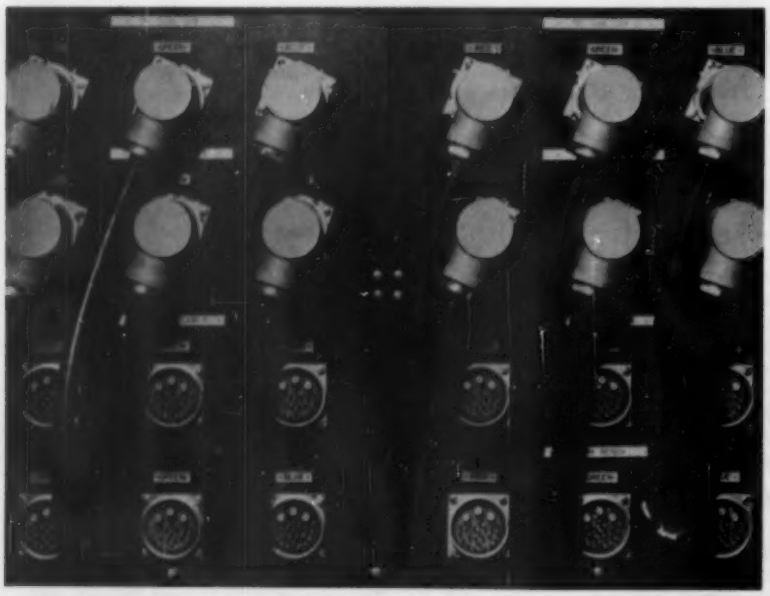


Fig. 8. Wall-mounted camera patching panel at Studio 72. Camera signals from eight locations in the studio terminate on the eight sets of receptacles. Any camera can be patched into the desired camera control by means of the patching cables. The location of this camera patch panel is shown in Fig. 4.

equipped workshop. Next to the workshop is the color telecine room containing 35mm, 16mm and slide film scanning equipment. The 14 racks of equipment in this telecine room house the audio, video and monitoring facilities associated with the film channels.

The control room at the right in Fig. 5 is a conventional monochrome control room equipped with four camera channels and associated video, audio and communication facilities. Pulse generation and distribution equipment and video switching and distribution facilities are installed in the small adjacent equipment room.

Color Video Facilities

Figure 9 is a simplified single-line line diagram of the video facilities in the color control room and adjacent telecine room. As can be seen, four tri-tube studio camera chains have been provided. The red, green and blue signals from each studio camera pass through a camera channel which consists of an aperture compensator, channel amplifier and gamma correction amplifier together with the necessary control and monitoring facilities. The red, green and blue signal from each camera channel are then combined to form an FCC standard encoded signal by means of an encoder in each of the camera channels. The encoded camera signals are then fed into the video switcher. Separate control room color monitors are associated with each of the four studio cameras.

Built-in test, alignment and measuring facilities are important elements of the camera channels. Step-wave signals have been provided to each camera channel for adjustment of the gamma circuits. Provisions have also been made to permit test signals to be connected to the encoders and color monitors. A selector switch at the input of each encoder permits unencoded color bar signals to be connected to the input of the encoder in place of the camera signals. Other selector switches permit encoded color bar signals or convergence dot pattern signals to be connected to the input of color monitors.

Tests charts also play an important role in camera alignment and adjustment. Special gyrating chart holders, which hold a registration chart for adjustment of camera scanning registration, a resolution chart for general camera alignment, and a gray scale chart for tracking and shading adjustment, are provided for camera alignment and adjustment. One of these test chart holders is shown in Fig. 10.

The Studio 72 telecine room is equipped with color film scanning facilities to handle 35mm, 16mm, and slide program material. The red, green and blue signals from each of these flying-spot devices pass through a film channel consisting of a phosphor correction amplifier, red

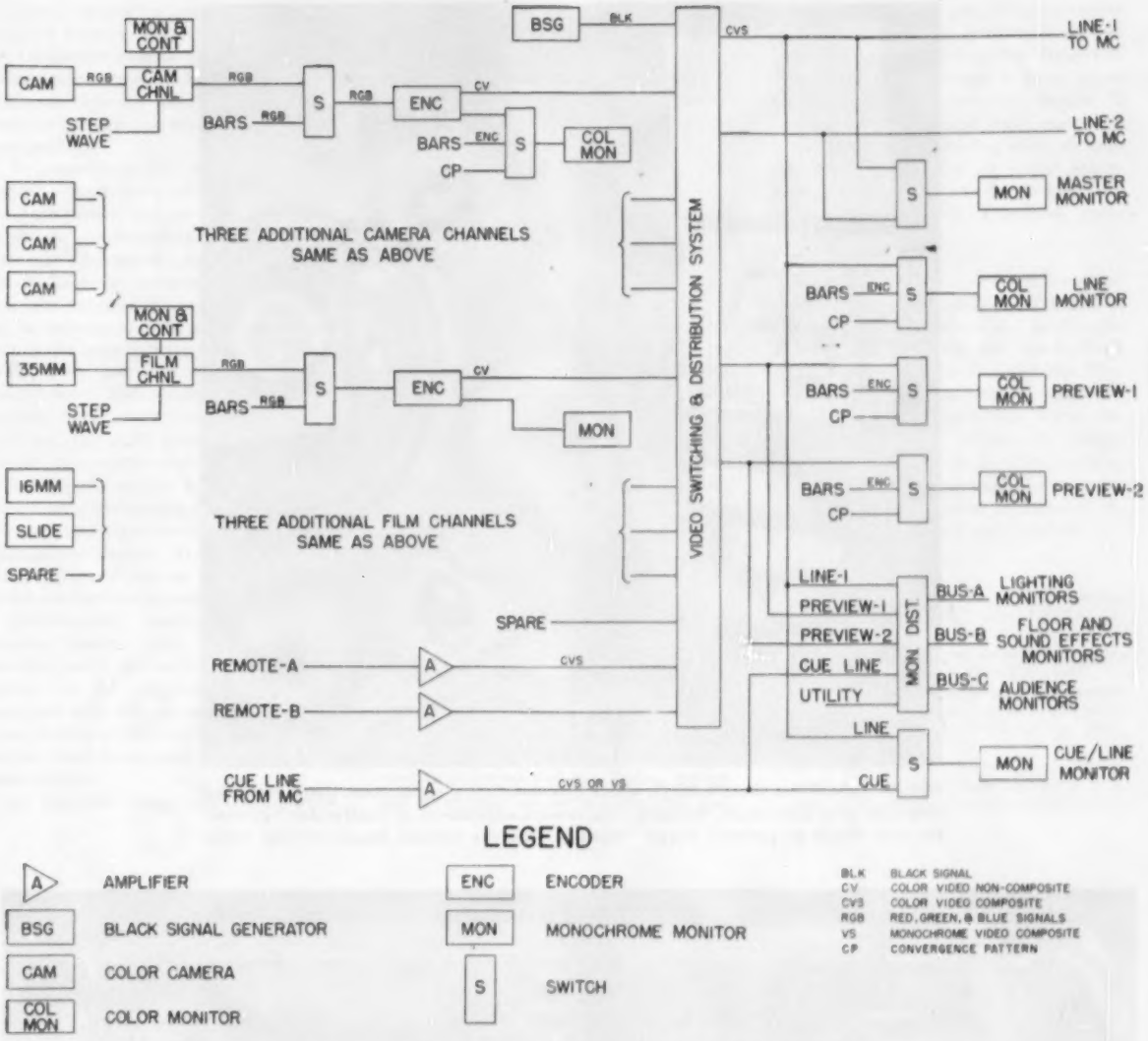


Fig. 9. Simplified single-line diagram of the color video facilities in Studio 72.

and blue channel bandwidth limiting amplifier, aperture compensator, blanking insertion and gamma correction amplifier, and masking amplifier. The red, green and blue signals are then encoded and fed into the video switcher.

A relay-type video switching system which follows a general design used for some time in CBS Television monochrome installations[3] is employed at Studio 72. The video switching console is shown in Fig. 11.

The switching system provides inputs for as many as five studio cameras, four telecine cameras or scanners, two remote signals, and a black signal generator. The latter is necessary to maintain the subcarrier "burst" signal when the picture is faded or switched to black. The switching system features a double dual-fader mixing arrangement that makes it possible to dissolve into or out of superimpositions which have been set up and previewed in advance. Provisions have also been made for the use of a wipe and montage amplifier for special effects and the switching system also permits dissolving into split screen or montage effects that have been set up and previewed in advance.

The video switching and distribution system transmits video program material to the CBS Television New York Master Control over special coaxial cable circuits. It also feeds video program material to the many picture monitors in the control room and at other points in the theater. As can be seen in Fig. 9, a monitor bus system is employed which permits a selection of program material to be transmitted to different groups of picture monitors.

Audio and Communication Facilities

A standard CBS 3E audio and communication system is employed in CBS Television Studio 72. Inasmuch as these facilities have already been described[3] only a brief review will be given here.

The audio console is completely self-contained and follows well-known CBS audio design practices. It is capable of simultaneously mixing 21 of 28 normally connected program sources. These sources include 11 studio microphones, one announcer's microphone, six audience microphones, two transcription turntables, four film sound tracks, two remote lines, a sound effects line, and a reverberation line. Regular and emergency program and monitoring channels are provided. An outstanding design feature of the console, and for that matter all audio and communication equipment in Studio 72, is the use of only two types of plug-in amplifiers and only two types of vacuum tubes.

The audio installation, in addition to the audio console, includes two trans-

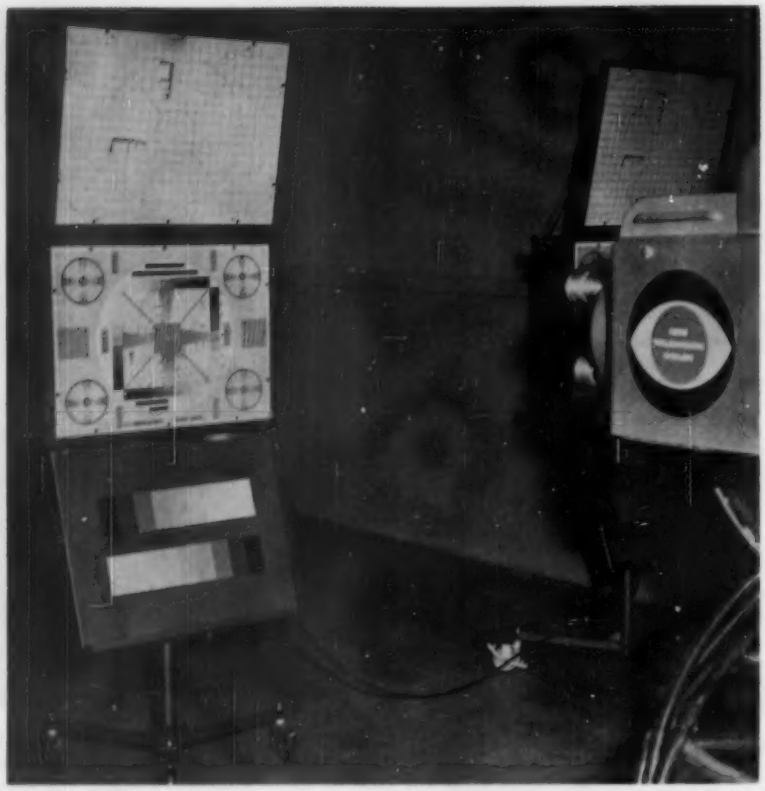


Fig. 10. Special test chart holders, which accommodate a registration chart, resolution chart and gray scale chart, facilitate color camera adjustment. A small motor "gyrates" the test charts to prevent image "burn in" on the camera image-orthicon tubes.

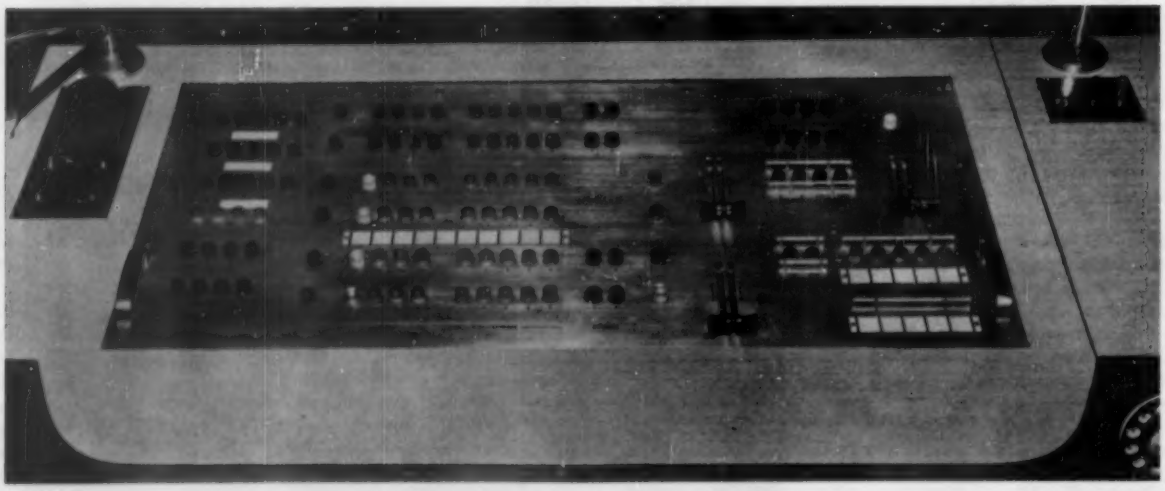


Fig. 11. Close-up of the video switching panel.

Switching is accomplished by means of the color-coded pushbuttons which are internally illuminated when the particular circuit is activated. The panel is capable of switching, fading, dissolving or super-imposing among ten noncomposite signals, as well as switching to either of two composite signals from remote pickup points.

Switches, fades, dissolves and superimpositions are accomplished on the lower four rows of buttons in the center portion of the panel. The dual faders associated with these rows of pushbuttons make it possible to dissolve into or out of a superimposition. Wipe and montage effects can be created by means of the fader control and pushbuttons at the lower right. Any of the composite or noncomposite input signals can be previewed on either of the two color preview monitors by means of the two top rows of push buttons.

The lower group of buttons at the extreme left side of the panel are for remote control of four telecine film scanners or projectors. These film devices may be started, stopped, or "still-framed," that is, a single frame of film can be projected continuously. The group of buttons at the upper left permit various signals to be transmitted to picture monitors in the studio by means of the monitor bus system.

scription turntables with a small associated control unit, a rack containing all equipment associated with audience sound reinforcement loudspeakers and audience reaction microphones, and a rack containing the studio communication facilities.

To coordinate the activities of the many persons involved in a television program production, an extensive system of studio communication is required. Two-way telephone circuits are provided between cameras and camera controls, between the sound effects man on the balcony and the audio mixer, and among the large lighting staff. A two-way loudspeaker intercom system links the control room and telecine. Program cue signals, the director's microphone circuit, and the audio mixer's microphone circuit are distributed to headphone outlets in the studio for use of sound effects men, orchestra leaders and microphone boom operators. The director's microphone circuit is also fed to receiver-equipped roving personnel, such as the studio floor manager, by means of a low-frequency induction-field transmission channel. All communication circuits except the carbon-button transmitters in the telephone circuits are equipped with thermistor-controlled volume limiters which maintain a uniform volume level throughout the communication system.

An extensive interphone system provides communication among lighting personnel at nine different operating locations. This communication system features a single-stage transistor amplifier at each station to assure adequate headphone level even in the presence of loud sounds such as produced by a nearby orchestra.

As shown in Fig. 2, sound effects originate from a sound-effects station on the balcony overlooking the staging area. In addition to the usual array of sound-effects devices, this station is equipped with a CBS Television sound-effects console[4] that provides all facilities normally required to handle the sound-effect requirements of the most complex television program. The sound-effects console transmits the complete sound-effects portion of the program to the audio console in the control room where it is mixed with audio from studio microphones and other sources. The sound-effects console also transmits sound effects to stage loudspeakers so the sounds can be heard by the performers.

Conclusion

Much can be said or written about the merits of a television studio, but a really well-designed studio involves much more than the ability to produce good sound and pictures. The actual proof of performance of a studio design takes place after all of the work of installation, testing and measuring has been completed and the studio has been placed in operation. It is then, under the pressure of day-to-day program production, that the soundness of the studio design is found to be satisfactory or unsatisfactory. Studio 72 has passed this test of daily operation with flying colors, having been in continuous operation for an entire season and having produced the largest and most elaborate CBS Television color productions.

A great many people were involved in the design of Studio 72; as a matter of fact, the design of the video and audio facilities represents the combined efforts of all members of the Audio-Video Div. of the CBS Television General Engineering Dept. The project was under the general guidance of William B. Lodge, Vice-President, and A. B. Chamberlain, Chief Engineer. It was carried out under the immediate direction of Howard A. Chinn, Chief Audio-Video Engineer.

References

1. R. S. O'Brien, "CBS color-television staging and lighting practices," *Jour. SMPTE, 63:* p. 41, Aug. 1954.
2. H. A. Chinn, *Television Broadcasting*, p. 552, McGraw-Hill Book Co., New York, 1953.
3. H. A. Chinn, R. S. O'Brien, R. B. Monroe and P. E. Fish, "CBS Television City technical facilities," *Proc. IRE 42:* p. 1067, July 1954.
4. R. B. Monroe and Price Fish, "CBS-TV sound effect console," *Audio Eng., 34:* p. V12, Mar. 1950; and *34:* p. V12, May 1950.

Broadcast Studio Redesign

By LEO L. BERANEK

A review is made of psychoacoustic and audience-opinion information of recent and older sources from which criteria for studio design are drawn. New criteria are proposed for reverberation time for studios and auditoriums used for speech, music and general purposes. Examples of three types of existing studios that need revision are discussed. Their physical properties and acoustic data are presented and the manner in which they do not meet the criteria is discussed. Various alternatives for adapting these studios to meet the criteria are presented. Emphasis is placed on achieving the desired results with a minimum outlay of money.

With the advent of television, broadcast studio design has become a neglected subject in the United States. Nevertheless, there are many broadcast studios in active use today for such purposes as announcing, drama, chamber music and panel discussions that are known to be unsatisfactory; yet their owners do not wish to underwrite an expensive reconstruction job in order to render them of the quality of the best studios in this country[1,2] and abroad.[3] Due in part to the necessity for replacement of war-damaged buildings, extensive research into the design of studios has been undertaken in Germany[4-6] and England.[7-13] Also, many studios have been redesigned recently in Switzerland[14-15] and France,[16] and the results have been made available.

In this paper, an approach to the redesign of smaller broadcast studios is presented with special emphasis on achieving the desired results with a minimum outlay of money. The criteria to be met are presented, along with the procedures of measurement of the acoustical properties. Structures for achieving the desired correction are presented and examples of three studios of two sizes with several types of defects are discussed in detail.

I. CRITERIA

A. History

In Ref. 3, the important criteria for studio design were presented as agreed upon by many broadcasters about five years ago. Statements were made there about (a) nonparallelism of the studio surfaces to produce diffusion of the sound field, (b) freedom from echo, (c) freedom from flutter echo, (d) reverberation time in the 500 to 1000 cycles/sec region as a function of volume (see Fig. 1), (e) reverberation characteristic as a function of frequency that is flat for speech studios and rising at low frequencies for music studios, (f) sound decay curve that is smooth logarithmic at all frequencies, (g) reflecting canopy or stage enclosure that surrounds the orchestra in large studios, (g) ambient noise level that is less than 25 db when read on the A scale of a standard sound level meter, and (h) transmission loss of more than 65 db through the common walls of adjacent studios. Although most of these criteria are today still accepted by the majority of broadcast engineers, recent information has modified, to some extent, Items (a), (b), (d), (e) and (f). These items are discussed below.

B. Reverberation Time

The solid-line curves of Fig. 1 were proposed in 1950 by the author[3] after studies of the reverberation times in studios that were judged to be "good" in the Danish, Norwegian, Don-Lee and NBC broadcasting houses. The preferred studios of the British Broadcasting Corp.[7] are shown by the letters T, G, M and H in Fig. 1, and are shown to conform very closely to the proposed curves. One might think as a result that there is nothing new to be learned. However, recently, Kuhl of Germany[6] has undertaken an extensive study of the preferences of listening audiences. His article, being in German, is summarized here to make clear the conditions of his evaluations.

About twenty studios or halls ranging in size between 70,000 and 500,000 cu ft were used in Kuhl's tests. Orchestras played parts of three musical compositions in each of these halls as follows: (1) as an example of classical music, the Jupiter Symphony in C-sharp (K.V. 551) of Mozart namely, the first movement from the 269th measure to the end and the second movement from the beginning to the 18th measure, with average playing time of 2½ min; (2) as an example of romantic music, the Fourth Symphony, in E-flat, of Brahms, including the end of the fourth movement, beginning four measures before the letter F in the small Eulenberg score, with average playing time of 2½ min; and (3) as an example of modern music, "Le Sacre du Printemps" of Stravinsky, comprising excerpts from "Danse Sacrale" including the final passage, with average playing time of 2¾ min.

In most cases the conditions for the pickup were: (a) one standard pressure microphone, (b) a bandwidth of 12,000 to 15,000 cycles/sec and (c) spacing of the microphone from the nearest instrument by at least 15 ft, since at this distance the ratio of the reflected sound energy in all rooms was equal or greater than the direct sound. The microphone was then put in the best place according to the sound engineer. In four cases two-microphone pickup was necessary.

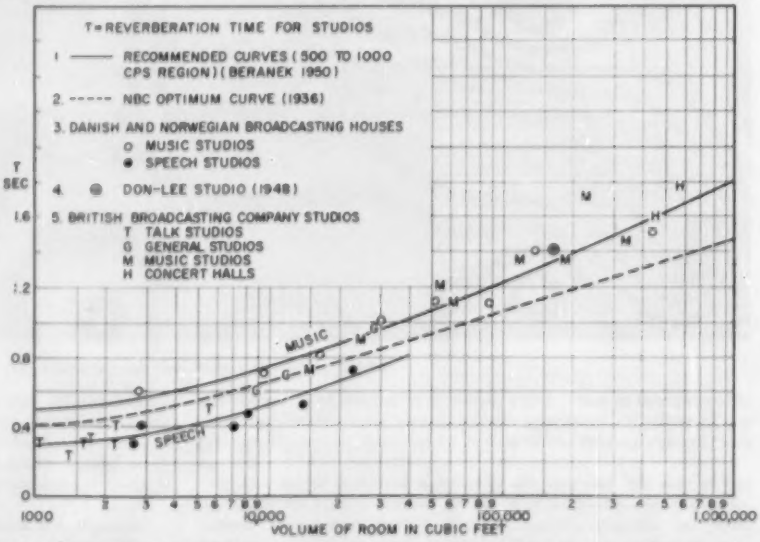


Fig. 1. Data showing reverberation times in the 500 to 1000 cycles/sec region in use in the U.S.A., Denmark, Norway and Great Britain including curves recommended by the author in 1950.

A contribution submitted July 22, 1955, by Leo L. Beranek, Bolt Beranek and Newman Inc, 16 Eliot St., Cambridge 38, Mass. This paper was presented on May 25, 1955, at the Washington, D.C., meeting of the National Assn. of Radio and Television Broadcasters.

Complete physical data on the studios or halls are given in his paper.

The recordings were played back to the listening subjects in rooms with volumes between 2000 cu ft and 5000 cu ft, having a reverberation time of 0.5 sec. The listening subjects included one group of about 120 musicians and a second group of 150 sound engineers, room-acousticians and other engineers conversant with acoustical matters. A third group of about 120 persons was drawn from an international congress and included about 30 musicians from eight nations. In all, 13,000 judgments were made.

The subjects were asked to pay attention to all of the acoustical conditions, namely, the reverberation, the clarity of the tone picture, i.e., the ability to perceive the individual instrument groups both by the position of the notes and by the precision of attack, and finally to pay attention to the "running" tone. They were asked to judge as little as possible the musical interpretation and the technical deficiencies. On questionnaires, there were squares to check for indicating whether the music was pleasing or not; whether the reverberation was too great, satisfactory, or too little; whether the "definition" was good or bad; whether the "running" tone was good or bad. There was also a space for remarks in which the participant could write anything that came to mind. The judgments were usually closed with a discussion over the recordings and the test methods. All participants seemed to be convinced of the validity of the judgments.

The test results reveal that the subjects preferred a reverberation time in the 500- to 1000-cycles/sec region of a little more than 1.5 sec for the Jupiter Symphony, about 2.1 sec for the Fourth Symphony of Brahms, and a little less than 1.5 sec for "Le Sacre du Printemps" by Stravinsky. The values do not depend on the volume of the rooms and were verified in every test by small tolerances. These values are for occupied rooms and would have to be higher if the reverberation measurements were made with the room empty. The most favorable compromise for different musical styles is a time of 1.7 sec for occupied rooms, i.e., occupied by the orchestra and the audience. There was no indication that a rise in reverberation time at low frequencies was desired, although it was not objected to in very large halls. In fact the large music studio in Baden-Baden, with a volume of 225,000 cu ft and a falling reverberation time at low frequencies was judged as one of the best and has had a very good reputation throughout its life. At 10,000 cycles/sec, the reverberation time was almost never above 1 sec because the losses in the air itself control the reverberation in the large halls.

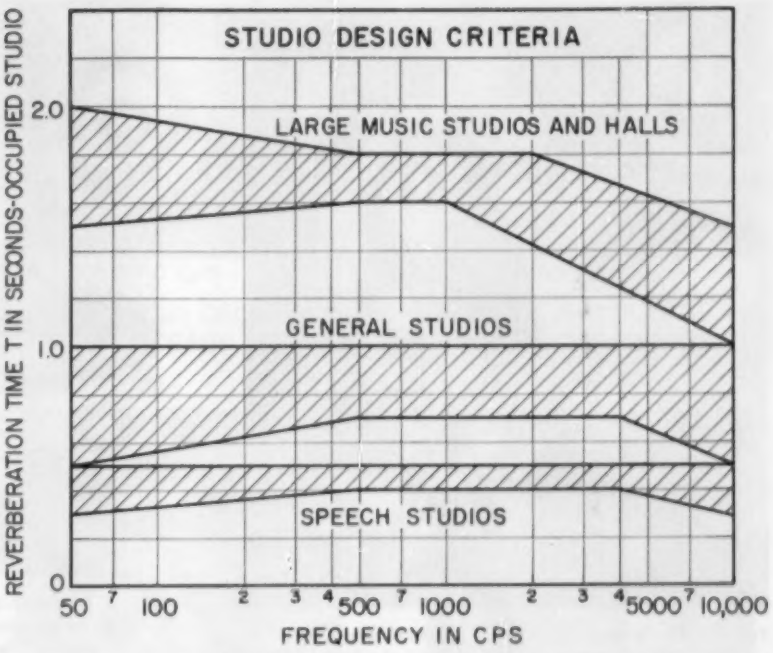


Fig. 2. New reverberation time curves suggested by the author based on studies of Kuhl[6] and the author's experience.

(This ends the summarizing of Kuhl's paper.)

The author believes that Kuhl's results are valid for symphonic music played over single-channel broadcast systems. Kuhl, the author and some broadcast engineers believe that his results are also applicable to binaural listening. The lower reverberation times of Fig. 1 were, according to published information, arrived at by policy decisions of the organizations cited, and not by controlled psychoacoustical experiments.

In regard to the shape of the reverberation curve with frequency, Chinn of the Columbia Broadcasting System[17] indicates that the best studios of CBS have had lower reverberation times at low and high frequencies than in the 500- to 1000-cycles/sec range of frequencies. Furrer of Switzerland in a recent private communication says the policy of the Swiss is "minimum possible reverberation on the low-frequency end, rising to higher value in the medium frequency band and avoiding as far as possible a drop at the other end. For big concert halls (175,000 cu ft and up) a small rise toward low frequencies seems, however, still desirable." Somerville[7] of the British Broadcasting Corp. says "B.B.C experience is that the reverberation curve should be reasonably level, and that a [sizeable] rise at low frequencies causes bass masking, especially in music with heavy scoring in the bass. At high frequencies a slightly drooping curve above 3000 cycles/sec is preferred."

Experience of almost all broadcasting agencies has indicated that for best results from speech studios, the reverberation time should lie between 0.3 and 0.6 sec, with the optimum values being between 0.4 and 0.5 sec. The reverberation at low frequencies should be either the same as in the 500- to 1000-cycles/sec region or lower. The reason for the low reverberation times for speech studios is that reverberation tends to make speech more difficult to understand, especially in single-channel systems. Reverberation times of 0.5 sec or less interfere very little with speech for microphone-to-announcer separations that are not over 4 ft.[17]

General studios, it seems, should be chosen to favor speech because they are more often used for drama, discussion panels, quiz shows and the like rather than for the playing of orchestral music. Chamber music also, sounds best in a relatively dead room (T = 1 sec) because it has traditionally been written for the drawing room.

On the basis of these recent studies, it seems appropriate to develop a family of reverberation curves for different sizes and types of studios. Recommended design criteria interpreted by the author at this time are summarized in Fig. 2. The shaded areas indicate the tolerances that may be permitted without causing noticeable differences to a radio listener in the quality of the music broadcasted. The shaded area for general studios is made large so that the broadcaster may decide for himself whether to make the



Fig. 3. Photograph of a nondirectional multiple loudspeaker source and a highly directional microphone (after Thiele[10]).

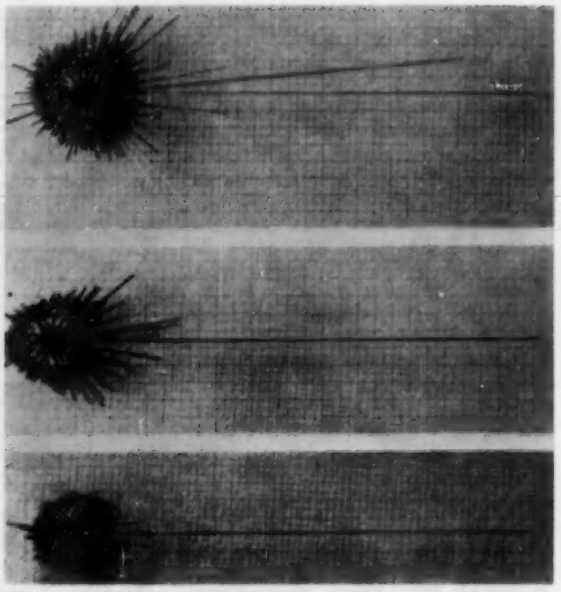


Fig. 4. "Hedgehog" curves showing the distribution of sound intensities in direction as measured in three rooms with the equipment of Fig. 3. Upper: room with good diffusivity; middle: room with medium diffusivity; lower: room with most of sound coming directly from the source (after Meyer[10]).

compromise more in favor of music or of speech.

C. Diffusivity

It has long been known that truly rectangular rooms with only two opposing walls that are flat and hard are not as good as rooms with irregularities on the walls and ceiling. In the first place, a "flutter echo" is produced between two opposing flat walls which results in a very unsatisfactory acoustical effect. In addition the frequencies of the normal modes of vibration are likely to be bunched so that there are, at least at low frequencies, frequency regions in which certain tones are emphasized, and other regions in which they are suppressed. In the earlier paper,[3] it was suggested that the walls be splayed or skewed so as to give a more uniform distribution of the normal modes along the frequency scale. Skewed walls also make the sound field more diffuse so that there are fewer positions in the room in which extreme variations in sound pressure occur as frequency is varied. It has been common practice to splay a wall by not less than 1 ft in each 20 ft of length. Additional fine scale irregularity on flat splayed walls is also desirable. Similarly, the ceiling and floor of the studio should be nonparallel. Actually, when a room has optimum reverberation time with the absorbing material distributed in patches on the ceiling, walls and by rugs on the floors, only moderate splaying seems necessary to give adequate diffusivity. The reverberation time must be measured so as to yield the detailed curve shown in Fig. 12 later in this paper.

Much attention has been given recently in the literature to diffusivity. In 1950, Bolt and Roop[12] defined "frequency irregularity" of a steady-state transmission curve as the sum of the differences, in decibels, between adjacent peaks and valleys divided by the frequency interval over which the summation is made, i.e.:

$$F_f = \frac{\sum_{f_a}^{f_b} SPL_{peak} + \sum_{f_a}^{f_b} SPL_{valley}}{(f_b - f_a)} \text{ db/cps} \qquad (1)$$

where F_f is the transmission irregularity per cycle measured over the finite frequency band between f_a and f_b, SPL_{peak} is the sound pressure level in decibels at a peak in the transmission curve, and SPL_{valley} is the sound pressure level in decibels at a valley in the transmission curve. The summations are taken over all peaks and valleys in the specified frequency band. They showed that at high frequencies the value of F_f is essentially dependent upon the reverberation time. Also at very low frequencies there is an insufficient number of normal modes of vibration to make such a quantity mean much. In some intermediate frequency range, the transmission irregularity seems to be a function of the state of the diffusion of the sound in the room and reaches a maximum value at some particular frequency, f_{max}. The approximate formula for determining this frequency is:

$$f_{max} = 2.5 \times 10^3 \sqrt{\frac{T}{V}} \text{ cps} \qquad (2)$$

T is the reverberation time in sec at that frequency and V is the volume of the room in cu ft. Their studies would lead one to the conclusion that if means are incorporated into the room for producing a diffuse sound field, they should be designed so that their effectiveness is a maximum at the frequency given by the above formula.

Furrer and Lauber[14] attempted to use a measurement of frequency irregularity as a means of sorting out two "unsatisfactory" Swiss studios from a group of ten studios ranging in volume between 1300 cu ft and 550,000 cu ft. The two studios in question (one was a concert hall) had volumes of 17,000 and 330,000 cu ft, and their reverberation times were in accordance with good design. In Furrer's and Lauber's tests the microphone to loudspeaker separation was such that the ratio of the reverberant energy density to the direct energy density was always greater than 5, i.e., so that

$$d = \sqrt{0.1A} \qquad (3)$$

where, d is the separation and A is the room absorption in sabins. They then determined F_f at two frequencies, 375 and 1650 cycles/sec and plotted these for the ten rooms as a function of room

volume. Their results were unsatisfactory as they showed no systematic differences and the plot did not separate out the two known bad rooms. They concluded that frequency irregularity is not directly a suitable criterion for room acoustics.

Schroeder[4] and Kuttruff and Thiele[5] show, respectively, theoretically and experimentally, that for all rooms where the frequency

$$f > 0.25 \times 10^6 \sqrt{\frac{T}{V}} \text{ cps} \qquad (4)$$

the frequency irregularity F_f is about 1.4 T db/sec, where T is the reverberation time in sec and V is the room volume in cu ft. Their conclusions agree with those of Furrer and Lauber. At this time, therefore, it is not clear that frequency irregularity can be used to evaluate studios.

Thiele[19] and Meyer[20] describe a quantity "directional diffusivity" which is a three-dimensional plot of the sound pressure level (measured by a highly directional microphone) as a function of the directional angles in space. Thiele describes (Fig. 3) a microphone in a parabolic mirror, about 4 ft in diameter, and a spherical sound source, consisting of many loudspeakers in a spherical housing. A medium frequency range with a warble tone 2000 cycles/sec is selected; the directional selectivity (3 db down points) is then 10°. The results are plotted in a hedgehog-like form as shown in Fig. 4, where the length of each spike is proportional to the energy coming from the corresponding direction. The upper "hedgehog" photo is for a case where there is good diffusivity. The lower photo is an example where the most sound is coming from the direction of the sound source, while the middle photo is between the other two in terms of diffusivity.

To reduce these "hedgehog" plots to a single number, Thiele has derived a formula yielding the directional diffusivity,

$$d = 1 - \frac{\Delta M \cdot M_0}{M \cdot \Delta M_0} \qquad (5)$$

where, M is the average energy coming from the non-directional source to the directional microphone in the room, ΔM is the average deviation of the spikes from the average M_0 in the room, and M and ΔM_0 have the same meanings, but for the source and directional microphone in an anechoic room. For a 100% directional diffusivity, d = 1; while for an anechoic room, obviously, d = 0.

Meyer[20] gives a plot of measured data in about 20 German broadcasting studios, selected because they had a good or rather good acoustical reputation among the users. The value of the directional diffusivity d varied uniformly from a value of about 0.50 for studios with volumes of 10,000 cu ft down to a value of 0.3 for studios with volumes of 300,000 cu ft. The spread in the data for the larger volumes is 0.15 and for the smaller ones about 0.1. This new measure of diffusivity seems to have face validity, but further time is required to determine whether or not the results can be correlated with subjective judgments that distinguish between "good" and "bad" studios.

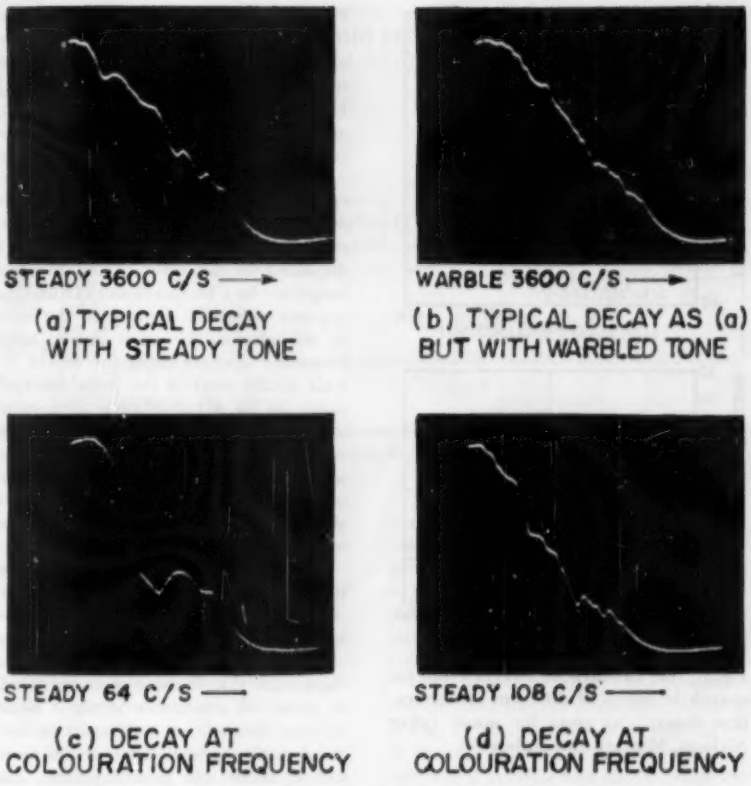


Fig. 5. Sound-decay curves measured by a cathode-ray oscillograph (after Sommerville[7]).

D. Coloration

Broadcasters have long expressed the opinion that sound decay curves (measured in a room far enough from the source so that reflected sound predominates in the steady state) should be linear when plotted as rms sound pressure level in decibels *vs* time. Chinn

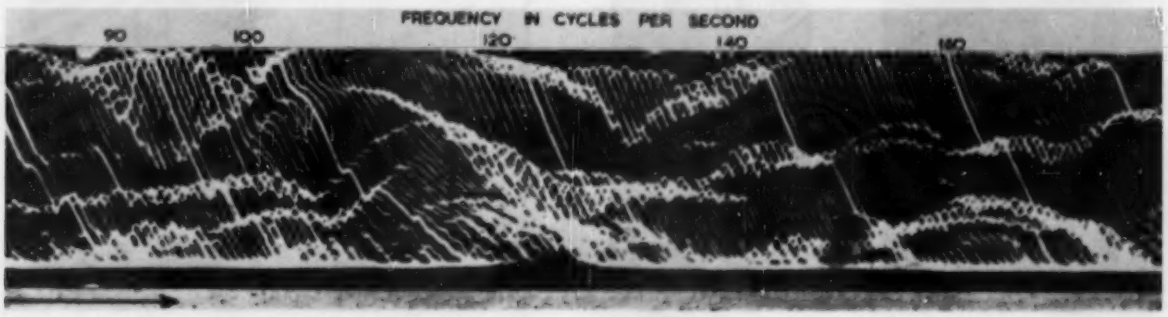


Fig. 6. Sound-decay curves superimposed so that the starting point of each curve of higher frequency is displaced slightly to the right (after Sommerville[7]).

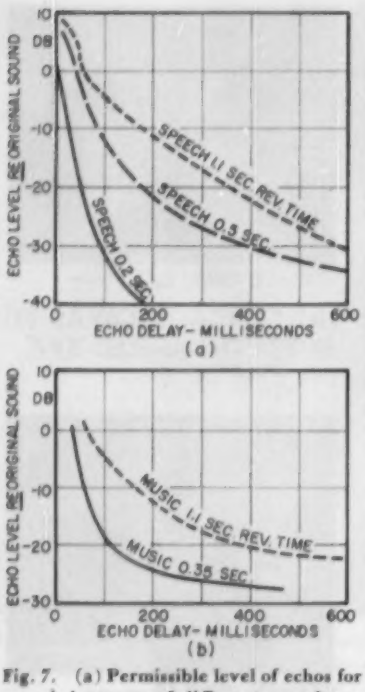


Fig. 7. (a) Permissible level of echos for speech in rooms of different reverberation times; (b) same for music (after Nickson, Muncey and Dubout[13]).

of CBS,[21] Goyder of the United Nations, Nixon and Gurin of NBC, Potwin and Maxfield[1] and others have stated this.

Somerville of the British Broadcasting Corp. has devised a technique for examining sound decay curves in a room in great detail. By this method, he produces a pulse of a pure tone of suitable length in the studio by a loudspeaker. This pulse is picked up by a microphone whose output is portrayed on the face of a cathode-ray tube. The amplitude of the pulse and the resulting sound decay is recorded on a film. Typical and atypical decay curves are shown in Fig. 5. Desirable curves are shown by the two logarithmic decay curves (a) and (b) while undesirable curves of two types are shown by (c) and (d). Undesirable cases reveal themselves by an increase after an initial fall in the curve or by a decay with a double slope.

In Fig. 6, a whole series of decay curves are shown, each at a different frequency superimposed so that the start of each curve of a higher frequency is displaced to the right of the previous frequency by a small amount. Thus, time appears along the bottom of the scale as the abscissa for each curve, while frequency appears along the top of the scale at the start of the pulse for each curve. In Fig. 6, cancellation phenomena are shown at the start of the decay curves near 90 to 100 cycles/sec and near 120 to 140 cycles/sec while severe coloration occurs in the curves just above 100 as shown by the opening out of the pattern in this region.

A sizeable increase in energy after the decay curve has fallen off for more than 0.3 to 0.7 sec is usually observed as a kind of echo and is very disturbing.

Chinn said that CBS has learned from experience that if there were not 40 db or more of reasonably straight decay at most frequencies and positions in a room using warbled tones as the sound source, there will be complaints from listeners, performers and program directors.

E. Echos

Every sound engineer and acoustician recognizes that echos are undesirable. Haas[22]; Bolt and Doak[23]; and Muncey, Nickson and Dubout[10,13] have undertaken fundamental studies that have led to a tentative criterion for avoiding echos. The most recent version of this criterion is shown in the form of two graphs of Fig. 7, valid for speech and music. Several reverberation times are shown. The curves show the level that a reflected sound must lie below the direct sound for various times of delay if the reflected sound is to disturb less than 20% of average listeners.

II. PHYSICAL STRUCTURES FOR MEETING THE REVERBERATION CRITERIA

It is generally agreed that even though there are many factors that affect the quality of a studio (diffusion, echos, coloration, etc.), control of the reverberation time is of primary importance. Many existing studios can be improved markedly and economically by the simple means of installing properly designed reverberation control measures. In some cases the corrective measures may involve the reduction of reverberation at particular low frequencies, or in a wide range of low frequencies or at high frequencies. There are even times when it may be desirable to increase the reverberation at high frequencies. For these different tasks, particular physical structures have been developed for incorporation into existing acoustical walls.

Let us assume the case of a small speech studio where a bad "booming" condition exists that is traceable to the lowest normal modes of vibration at 40, 60 and 80 cycles/sec. To control these frequencies, resonant membrane absorbers may be used. These units were first suggested and used by C. W. Goyder, then Chief Engineer of All India Radio and now in the telecommunication division of the United Nations Permanent Headquarters in New York.[24] The unit consists of a membrane, behind which is a cavity that can be recessed into a studio wall or mounted on the surface. The membrane must consist of a material having

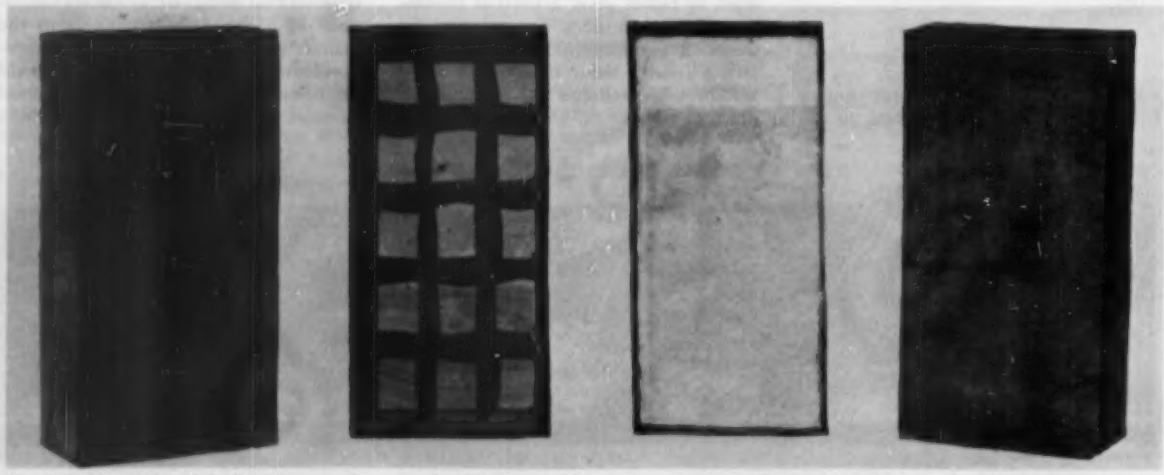


Fig. 8. Left to right: (a) vibrating membrane unit; (b) same with membrane removed; (c) quarter-wave absorber; (d) same, with cover to reflect higher frequencies (after Goyder[24]).

high internal friction for it is this material that provides the absorption.

The vibrating membrane unit used by Goyder is shown on the left of Fig. 8 and has the dimensions of 2 × 4 ft. The same unit with the membrane left off is shown in the second photograph from the left. The subdivisions of the air space are to reduce the possibility of transverse standing waves. They are made from corrugated cardboard of the type used in shipping cases. Sufficient space is left between the membrane and the cardboard to prevent contact.

The depth of the air space behind the unit is calculated from the formula,

$$f = \frac{c}{2\pi}\sqrt{\frac{\rho}{lm}} \qquad (6)$$

where f is the frequency of maximum absorption for the box, c is the speed of sound in air (344 meters/sec), ρ is the density of air (1.18 kg/cu m), l is the depth of the air space in meters and m is the surface density of the membrane in kilograms per square meter (multiply lb/sq ft by 4.88 to get kg/sq m). The membrane material should not resonate as a diaphragm, so plywood is not suitable. Goyder used linoleum, but Sommerville suggests bituminous building paper as being cheap and effective. Furrer uses some sort of soft building board. Dampened sheets of very thin aluminum, such as commercially available[28] sound damping tape may be used.

To test the vibrating membrane unit, the simple arrangement of Fig. 9, after Goyder, is used. The unit is stood up outdoors or in an anechoic chamber and

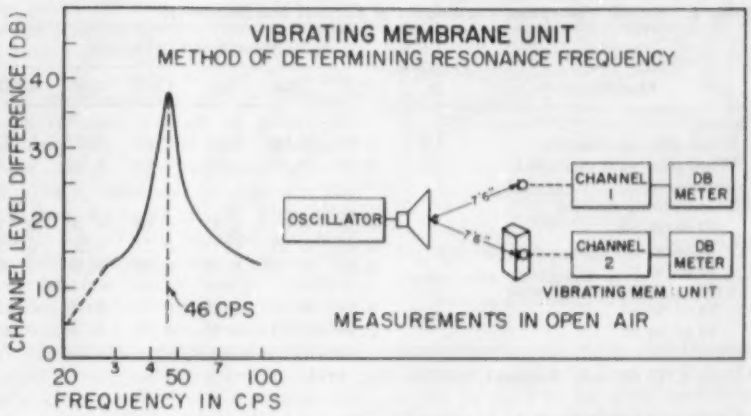


Fig. 9. Technique for measuring resonance curve of a vibrating membrane unit (after Goyder[21]).

a loudspeaker is placed in front of it. A microphone is put inside the box and another one is located the same distance away from the loudspeaker outside of the box. The differences between the sound pressure levels measured inside and outside of the box are measured and plotted as shown in Fig. 9. The peak should occur at the desired frequency of maximum absorption. The depth of the box may be varied by cutting it down and, thereby, raising the resonance frequency, or the weight of the membrane may be increased to lower the resonance frequency. To flatten the resonance curve so as to make the tuning less critical, an absorbing material may be introduced into the box in the fashion of Sommerville, shown in Fig. 10.

If it is desired to use plywood panels for low-frequency sound absorption, the data of Fig. 11 are available. Note that curves A through D were laboratory measurements and curve J was measured in the

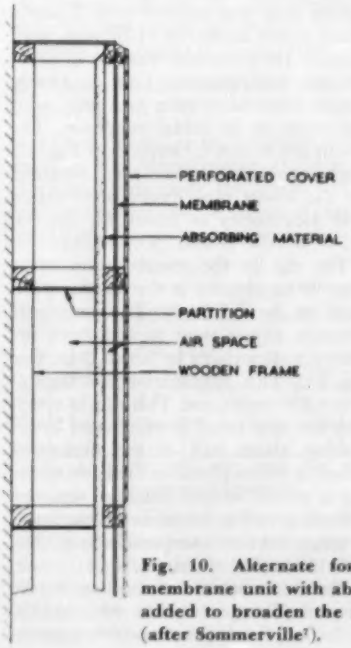


Fig. 10. Alternate form of vibrating membrane unit with absorbing material added to broaden the resonance curve (after Sommerville[7]).

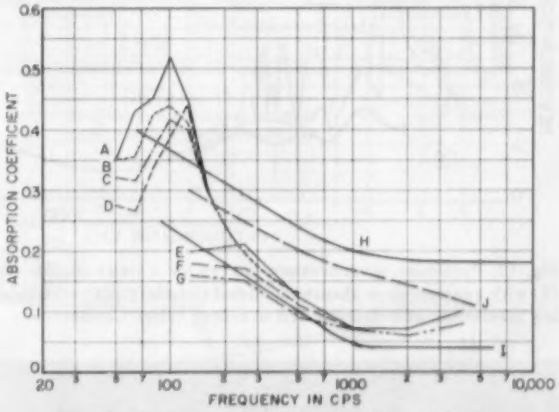


Fig. 11. Absorption coefficients for plywood panels.

Group I (A through D) British reverberation chamber data for 28 × 28 in. and 28 × 78 in. flat panels ¾-in. thick, framed around the edges by ¾-in. furring, screwed at 8 peripheral points and with 2-in. rockwool at the wall:

A. 4-in. air space, 1 crossbrace.
B. 4-in. air space, 3 crossbraces.
C. 3-in. air space, 1 crossbrace.
D. 3-in. air space, 3 crossbraces.

Group II (E, F, and G) American reverberation chamber data for 4 × 8 ft panels ½-in. thick, framed around the edges on 1 × 1½-in. furring. Two crossbraces randomly placed:

E. Panel directly on concrete wall.
F. ½-in. Kapok between panel and wall.
G. ½-in. Kapok cemented to panel and against wall.

Group III (H, I and J) actual installation in studios and a concert hall:

H. Polycylindrical panels of two ¼-in. sheets of plywood separated by tufts of felt impregnated with glue.
I. Polycylindrical panels of one ¾-in. sheet of plywood formed with steam and pressure.
J. Same type of panels as A through D as measured in Royal Festival Hall, London.

Table I. Sound Absorption Coefficients of Carpets and Draperies*

Material	Thickness, in.	Absorption Coefficients 125	250	500	1500	2000	4000
Carpets							
Wood pile, on concrete	3/8	0.09	0.08	0.21	0.26	0.27	0.37
Wood pile, with underpad	5/8	0.20	0.25	0.35	0.40	0.50	0.75
Draperies:							
Velour, hung straight							
10 oz/sq yd		0.04	0.05	0.11	0.18	0.30	0.35
14 oz/sq yd		0.05	0.07	0.13	0.22	0.32	0.35
18 oz/sq yd		0.05	0.12	0.35	0.48	0.38	0.36
Velour, draped to half area							
14 oz/sq yd		0.07	0.31	0.49	0.75	0.70	0.60
18 oz/sq yd		0.14	0.35	0.55	0.75	0.70	0.60

* From L. L. Beranek, Acoustics, McGraw-Hill, 1954.

field in a large concert hall using equal areas of the panels as for A through D. Also, curves E, F and G were laboratory measurements while curves H and I were measured in broadcast studios.

Less absorption at lower frequencies, but distributed over a range of about two octaves, may be obtained by following Goyder again. In this case, the membrane is replaced by an inch or two of low-density nonrigid glass fiber blanket. (See the third photograph from the left in Fig. 8.) The depth of the box is chosen to be equal to one-quarter wavelength at the highest frequency that good absorption is desired. Quite high sound absorption still is obtained down to one-fourth this design frequency. At higher frequencies, the absorption becomes that of the blanket with rigid wall backing. We shall call these units "quarter-wave absorbers."

If it should be desired to reduce the absorption of the blanket type of box at higher frequencies, the face may be covered with a thin sheet of plastic (like Mylar manufactured by Du Pont). The surface density of the covering should be chosen according to the formula,

$$\rho = \frac{500}{2\pi f} \qquad (7)$$

where, ρ is the surface density in kg/sq m, and f is the frequency above which it is desired to reduce the absorption. A perforated facing with holes properly chosen in size and number[35] may also be used in place of the plastic sheet (see right hand photograph of Fig. 8).

High-frequency absorption may be provided by carpets or draperies. Approximate sound absorption coefficients are given in Table I.

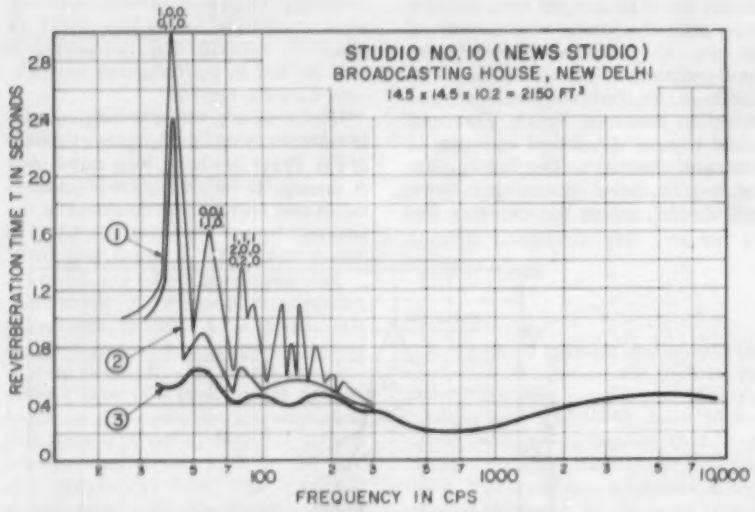


Fig. 12. Pure-tone reverberation curves for a news studio: (1) as originally built; (2) with quarter-wave absorbers added to ceiling; (3) with quarter-wave and vibrating membrane absorbers added to ceiling (after Goyder[34]).

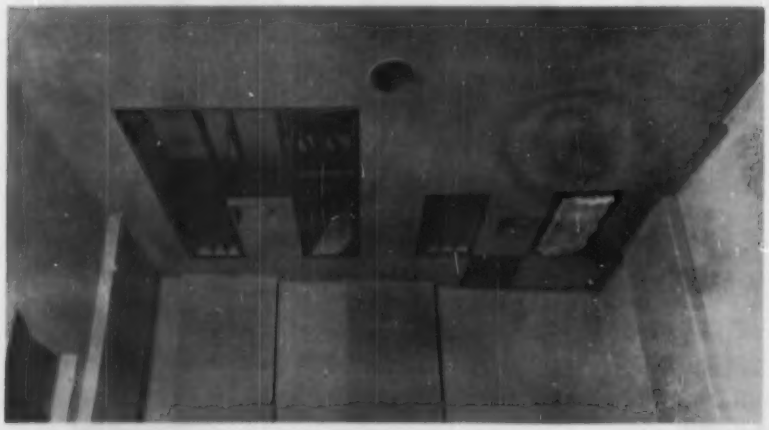


Fig. 13. Photograph of ceiling of the studio of Fig. 12 showing quarter-wave and vibrating membrane absorbers with covers removed (after Goyder[34]).

III. EXAMPLES OF STUDIO REDESIGN

A. Announce Studio, 14.5 ft × 14.5 ft × 10.2 ft = 2150 cu ft

This studio was redesigned by Goyder. The initial treatment consisted of a linoleum on concrete floor, a transite board hung false ceiling backed with 1½ in. glass wool blanket. Half of the wall surface area was covered with Transite board panels backed by 1½-in. glass wool blanket. His procedure was first to measure the reverberation time at closely spaced frequencies using *pure* tones, with the studio in its initial condition. The results are shown by curve 1 of Fig. 12. High reverberation times were obtained for the lowest nine modes of vibration with frequencies at about 39, 39, 55, 55, 67, 67, 78, 79 and 79 cycles/sec.

The dip in the reverberation curve near 700 cycles/sec is due to the treatment on the side walls. The perforated Transite panels were spaced from the plaster wall surfaces by about 2 in. (see Fig. 13). This combination resonates at about 650 cycles/sec. This dip in reverberation time could be eliminated by replacing about half of the perforated paneling with a plastic or linoleum covering of several surface densities, designed according to Eq. (6) to have resonances at staggered lower frequencies, say, 200, 150, 100 and 80 cycles/sec.

To obtain sizable absorption in the frequency range between 60 and 250 cycles/sec, five blanket-covered, quarter-

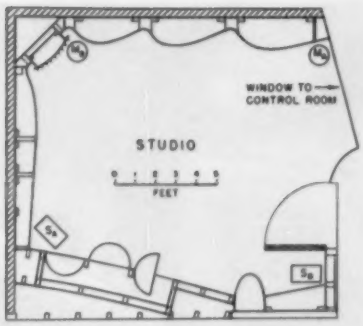


Fig. 14. Small studio at M.I.T. with non-parallel walls, ceiling and floor and lined with plywood of types for which data are shown by curves H and I of Fig. 11.

wave absorbers were constructed, each having a depth of 12 in. These were placed in the ceiling near the corners or at the edges, because the normal modes of vibration have their pressure maxima there. These five boxes constituted about 20% of the ceiling area (see Fig. 13).

Next the reverberation time was re-measured, this time with furniture in the room and curve 2 of Fig. 12 was obtained. Reduction of the lowest frequency peak was then accomplished by constructing five vibrating membrane units with faces of $\frac{3}{16}$ in. linoleum and with box depths of 14.5, 14.8, 15, 15.2 and 15.5 in. These were also placed in the ceiling at the corners or near the edges (see Fig. 13). The resulting reverberation time is shown by curve 3 of Fig. 12. If the dip at 650 cycles/sec were removed by the procedure given above, the reverberation curve would be essentially flat at a value of 0.4 sec which agrees closely with the design curve of Fig. 2 for speech studios. A further decrease in high-frequency reverberation could be obtained by the addition of a carpet or of draperies.

B. Speech Studio — Plywood Interior, 1620 cu ft

This studio was an experimental studio built at the Massachusetts Institute of Technology to study the absorption of plywood panels and the effects of curved panels and irregular and splayed surfaces

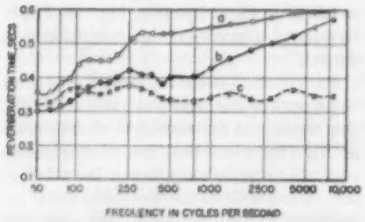


Fig. 16. Reverberation times in BBC studio with linoleum covered concrete floor: (a) original; (b) vibrating membrane, absorbers added; (c) carpet added and absorbers modified (after Sommerville[7]).

on sound diffusion (see Fig. 14). The room was intended to have a carpet (without underpad) on the floor when used with a small number of people. The reverberation times for the room with different numbers of people are shown in Fig. 15. The rise in reverberation time at high frequencies is quite obviously undesirable to a listener immediately on his entering it. The simple addition of a carpet over the entire floor with wool pile and underpad reduces the reverberation time to nearly a uniform 0.5-sec reverberation time, for an occupancy of 3 or less persons. If more people are to occupy the studio, the area of the carpet should be decreased to zero in a linear relationship as the number of people is increased to 20.

Sommerville[7] discusses the subjective reaction of listeners to a studio in England with a similar shape of reverberation

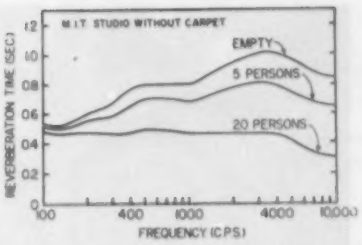
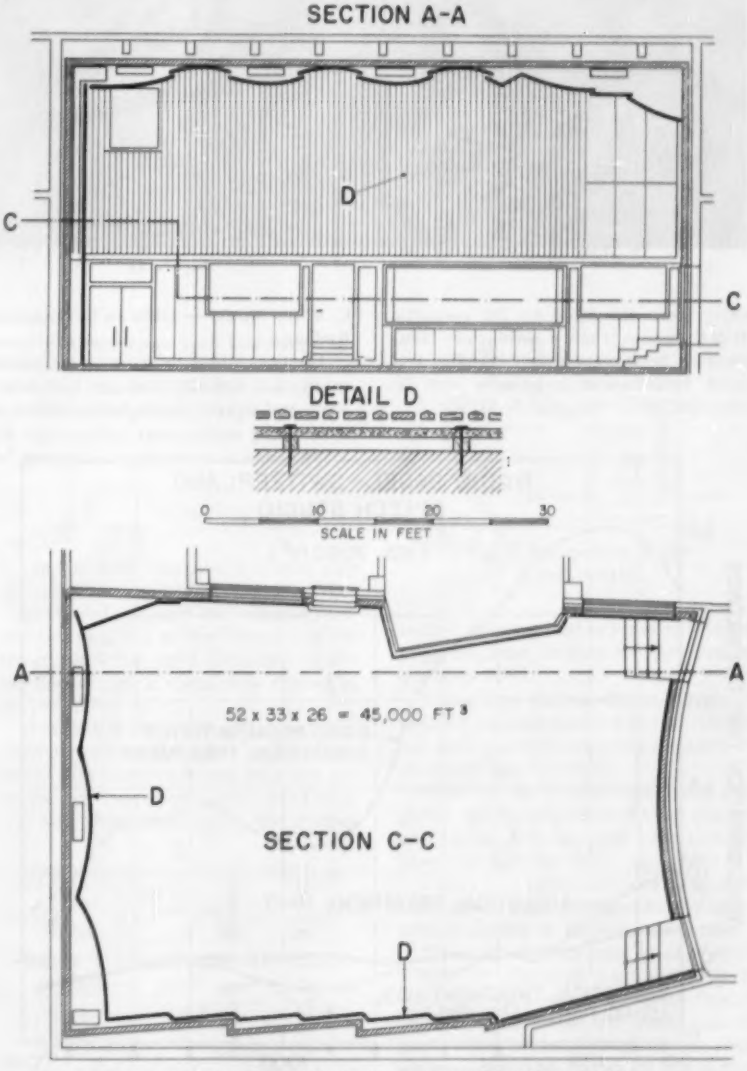


Fig. 15. Reverberation times in M.I.T. studio with linoleum covered wooden floor as a function of occupancy.

curve (see curve C of Fig. 16). He says, "The results [of recordings made in the studio for each of the three reverberation times] were assessed by a listening panel, and the preference was for the level curve at 0.35 sec. The conditions in the studio corresponding to the level



STUDIO - LAUSANNE, SWITZERLAND

Figure 17



Figure 18

curve were also liked by the speakers. It is fortunate when a satisfactory compromise between acoustic comfort and good broadcasting conditions can be obtained, as in this case."

C. Music Studio — 45000 cu ft, Complete Redesign

The next sample of redesign is a music studio that formerly had too high noise levels and was not particularly pleasing to the listeners. In redesign, a new floating floor was built by pouring about two inches of reinforced concrete over a mat made of glass fibers covered by Transite, sealed at the joints to prevent penetration of the concrete into the glass fibers. New walls isolated at the floor level were provided and a new ceiling was installed by hanging it on resilient hangers from the old ceiling (see Fig. 17). The material for reverberation control consisted of membrane absorbing units, consisting of a wooden frame 4 to 8 in. high on which a soft building board panel is mounted. Each unit has an area of about 10 sq ft. These units are tuned for 80, 100 and 120 cycles/sec. A pleasing appearance was desired by the owner so that the acoustical material was covered with wooden slats as shown in detail D of Fig. 17 and in Fig. 18. High-frequency absorption was provided by a carpet.

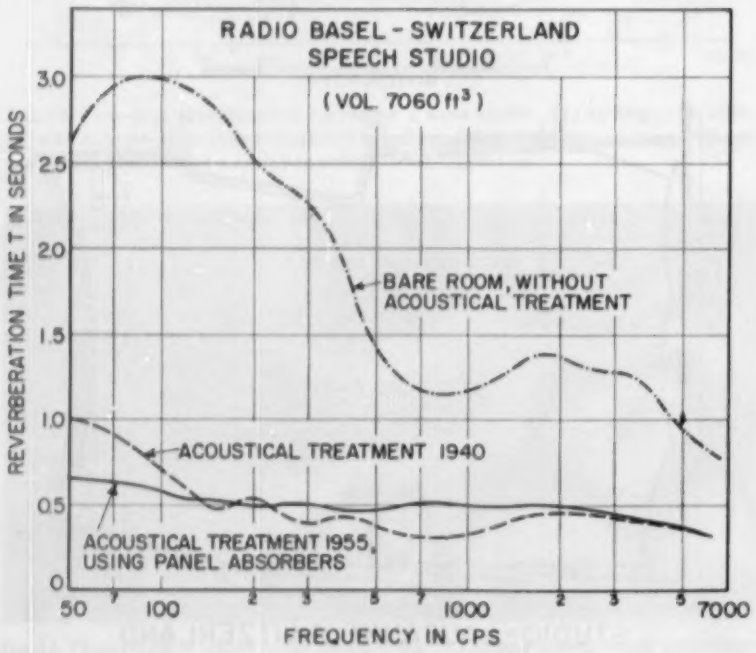


Figure 19

Reverberation curves before and after treatment of this studio are not available, but the results are similar to those shown in Fig. 19. Note that the reverberation curve is considerably flatter than before the changes and the low-frequency reverberation is reduced. Because the acoustically transparent slatted covering serves no purpose acoustically, it could be eliminated, as an economy measure, from the design and a lightweight, thin-coat, water-base paint could be sprayed on the soft building board to brighten it.

IV. CONCLUDING REMARKS

With the new criterion curves, reverberation-time measuring techniques, knowledge of how to build and test vibrating membranes and quarter-wave absorbers, it is possible to redesign existing studios or to modify them at low cost so that they will be satisfactory for the purposes intended.

The author wishes to thank Prof. W. Furrer of the P.T.T., Bern, Switzerland; C. W. Goyder of the United Nations Permanent Headquarters; Howard Chinn of CBS; and George Nixon and H. Gurin of NBC for their helpful discussions and material basic to this paper.

REFERENCES

1. C. C. Potwin and J. P. Maxfield, *J. Acous. Soc. Am., 11:* 48–55 (1939).
2. W. W. Caruthers and D. P. Loye, *J. Acous. Soc. Am., 21:* 428–434 (1949).
3. L. L. Beranek, *Proc. I.R.E., 38:* 470–474 (1950).
4. M. Schroder, *Acustica, 4:* 456–468 and 594–600 (1954).
5. H. Kuttruff and R. Thiele, *Acustica, 4:* 614–617 (1954).
6. W. Kuhl, *Acustica, 4:* 618–634 (1954).
7. T. Sommerville, Building Research Congress 1951, Paper Presented in Division 3, 53–59.
8. T. Sommerville and F. L. Ward, *Acustica, 1:* 40–48 (1951).
9. C. G. Mayo, *Acustica, 2:* 49–64 (1952).
10. R. W. Muncey, A. F. B. Nickson and P. Dubout, *Acustica, 3:* 168–173 (1953)
11. J. W. Head, *Acustica, 3:* 174–180 (1953).
12. T. Sommerville, *Acustica, 3:* 365–369 (1953).
13. A. F. B. Nickson, R. W. Muncey and P. Dubout, *Acustica, 4:* 515–518 (1954).
14. W. Furrer and A. Lauber, *Acustica, 2:* 251–256 (1952).
15. W. Furrer, Building Research Congress 1951, Paper Presented in Division 3, 49–51.
16. J. Pujolle and J. Boisard, Colloque International D'Acoustique Architecturale Marseille, April 1950, 100–109.
17. Unpublished CBS Engineering Department Report E397-C, "Broadcasting Studio Reverberating Characteristics," April 13, 1945.
18. R. H. Bolt and R. W. Roop, *J. Acous. Soc. Am., 22:* 280–289 (1950).
19. R. Thiele, *Acustica, 3:* 291–302 (1953).
20. E. Meyer, *J. Acous. Soc. Am., 26:* (1954).
21. Unpublished CBS Engineering Department Report E353-B, "Recording of Sound Decay," July 5, 1938.
22. H. Haas, *Acustica, 1:* 49–58 (1951).
23. R. H. Bolt and P. E. Doak, *J. Acous. Soc. Am., 22:* 507–509 (1950).
24. The material credited to Mr. C. W. Goyder was conveyed privately to the author in an unpublished BBC document titled, "Note on Reverberation of Sound in an Enclosed Space," dated May 31, 1943.
25. R. H. Bolt, *J. Acous. Soc. Am., 19:* 918–921 (1947).
26. For example: Permacel 12 Tape, Permacel Tape Corp., 1711 S. Grand Avenue, Los Angeles 15; and "Scotch" Brand Sound Dampening Tape, Minnesota Mining and Mfg. Co., Tape Div., St. Paul 6, Minn.
27. L. L. Beranek, *Acoustics*, pp. 406–415. McGraw-Hill Book Co., 1954.

Procedures of Registration in Process Photography

By ROBERT P. SHEA

The term "process photography" is used generally to encompass such arts as optical printing, glass and matte shot work, title insert work and color separation printing. This paper will discuss one phase of the problems of process photography, namely that of registration. To define this term more precisely, registration is the positioning of the film in the aperture of the specified intermittent prior to exposure. In this paper the discussion will be limited to registration in terms of intermittent mechanisms.

THERE ARE in the motion-picture industry at the present time two standard types of registration. These are known by the names of the original equipment manufacturers. These terms are Bell & Howell and Mitchell. They will be referred to as such in this paper. We shall refer to the location of the register pins as though looking from the lens into the intermittent, whether it be camera or projector head.

With Bell & Howell registration in the camera, the sound track is to the left of the aperture and the full-fitting pin is adjacent to the sound track. Both pins are above the aperture, as shown in Fig. 1, item A.

With Mitchell registration in the camera, the large pin and soundtrack are in the same location, but both pins are below the aperture (Fig. 1, item B).

In optical printing and color-separation printing, due to lens inversion of the image and left-to-right displacement, the location of pins is completely altered in the projector.

With Bell & Howell registration in the projector, often referred to as the "light head," the soundtrack and large pin are on the left. This seems to contradict what was said about the camera, but it must be kept in mind that in order to face the projector, from the lens, we have rotated ourselves 180°.

This places the soundtrack physically opposite from its position in the camera, and both pins are now below the aperture as seen in Fig. 1, item C.

With Mitchell registration in the projector, the soundtrack and large pin are also on the left, but now both pins are above the aperture as in Fig. 1, item D.

Figure 2, a perspective drawing, illustrates this change more graphically in the case of the Bell & Howell registration.

These are the two basic types of registration for 35mm photography. It is always necessary to use the same type of registration so that the same pair of perforations is used throughout any process sequence. The reason for this is twofold: first, because of slight imperfection in the perforating of the film; and sec-

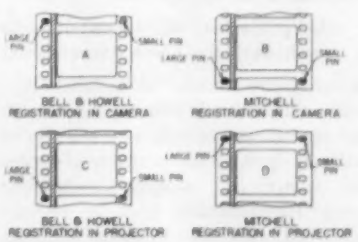


Fig. 1. Intermittents viewed from lens.

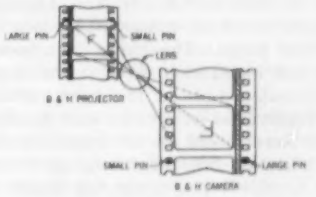


Fig. 2. Perspective of the optical system.

Presented on October 19, 1950, at the Society's Convention at Lake Placid, N.Y., by R. P. Shea, Producers Service Co., 2704 W. Olive Ave., Burbank, Calif.
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ondly, and mainly, because of shrinkage of the film due to developing and drying, and because of shrinkage due to the aging of stock.

In optically printing fine-grain master positives, it is necessary to run original or duplicate negatives with "heads up" in a reverse pin intermittent, which is a projector intermittent with the same type of standard registration as used in the camera, but with the large pin in reverse of its normal position. This reverse pin intermittent is necessary for any special effects that are made directly from original or duplicate negatives. In contact printing fine-grain master positives in the camera of an optical printer, it is necessary to use a reverse pin intermittent, as the negative has been reversed to allow emulsion-to-emulsion contact.

The term "heads up" is used to define the film in the projector head as being right side up, i.e. as the subject was when originally photographed. Normal procedure in optical printing is to have the film in the projector head "heads up" and the film traveling upward. The film in the camera would be traveling downward and photographing "heads down."

If a traveling matte, for illustration, were to be photographed on Bell & Howell registration, and then used as a matte on Mitchell registration, a fringe would be noted in the direction of the large registration pin. The color or density of the fringe would be dependent on the dominate record. This dominate record would also determine the location of the fringe. The main contribution to this registration error is shrinkage, as mentioned above. If the same system of registration were to be used throughout there should be no fringe encountered, unless differential shrinkage were to be involved, i.e., a varying degree of shrinkage from one portion to another portion of the same strip of film. Under good laboratory control, this is an almost non-existent condition.

In color separation work, the fringe mentioned above will appear as a definite colored line at every point within a frame where there is a change in color. As an extreme example, picture the edge of a man's black coat collar in contrast to a white shirt underneath it. If, for example, one color were to be misregistered, a line equal in width to the amount of misregistration would show up as a color fringe between the black coat and the white shirt.

This holds true of multiple insert shots; as the number of inserts increases, the possibility of fringes increases in a direct proportion. By the use of dupes, it is possible to transfer, optically, a Bell & Howell registration shot to Mitchell registration, or vice versa. It is also possible to transfer from one type of perforation to another, that is, from Bell & Howell to Dubray-Howell or Kodak Standard.

Though this process of duplicating tends to increase the contrast, it enables us to abide by the rule that the same system of registration be used throughout any process sequence. To perform the transfer operations, or any film emulsion reversals more efficiently, it is desirable to have equipment with interchangeable intermittents. They must be physically interchangeable and also they must be optically interchangeable, that is, the location of the register pins and aperture must retain an absolute relationship to the optical or illuminating center.

In color separation effects made from multi-emulsion or stripping film,* it is also desirable to have intermittents which are interchangeable, and which have both normal registration and reverse pin positions. By this it is meant that one intermittent would have the full fitting pin on the soundtrack edge of the film, and the other would have the full fitting pin on the non-soundtrack edge. This is because emulsion in the stripping process is transferred to its new base with the lens side of the emulsion to the base. The emulsion transfer from its original base is a process similar to the transfer of ink from type to paper. This, in practice, changes the registration from left to right on the two emulsions that have been stripped, but leaves the unstripped record in normal registration; therefore, it is necessary to have reverse pins in the intermittent of the step printer for contact printing of these two records. The unstripped emulsion is printed contact with normal registration. In optically printing the fine-grain dupes from these master positives, normal registration is used except that the record made from the unstripped emulsion is exposed

* J. G. Capstaff, "An experimental 35mm multilayer stripping negative film," *Jour. SMPTE, 54:* 445–453, Apr. 1950.

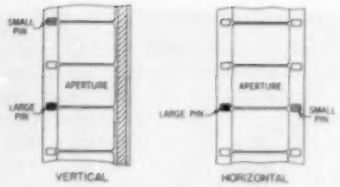


Fig. 3. 16mm registration.

with the emulsion toward the light source while the remaining two have the emulsion toward the lens. Any further procedure is carried out in the normal manner except that in color separation printing, shrinkage between different records is not always uniform. Therefore, it becomes necessary to correct for misregistration of the image itself with relation to the perforations being used. The above printing registration procedure would also apply to film photographed in a three-step camera.

It has been common practice for many years to locate the large registration pin adjacent to the soundtrack. It appears ideally that it should be on the opposite side because that is closer to the actual picture area and therefore less affected by shrinkage.

Registration in the soundtrack area is of no importance to process photography, as sound is added later.

In 16mm photography there are two types of registration, as shown in Fig. 3:

(*1*) *Horizontal registration* where the two pins are placed horizontally. One pin is full fitting in both directions and the other pin is full fitting vertically and undersized horizontally. This type of registration is used on double-perforated film.

(*2*) *Vertical registration* where the two pins are placed vertically. One pin is full fitting in both directions and the other pin is full fitting horizontally and undersized vertically. This is used on single-perforated film.

There are other register pin locations for 16mm film which sometimes must be used to ensure perfect cancellation, however, the locations illustrated and described were chosen because they place the pins in the closest proximity to the aperture and this reduces the shrinkage problem.

The inherent registration problems involved and described in 35mm film also apply to 16mm and the solutions are solved in the same manner.

The Evaluation and Control of Direct-Reading Color Densitometers

By W. LYLE BREWER, MURRAY C. GODDARD and STANLEY A. POWERS

Color densitometers are used in photographic laboratories for film processing control, printer control, print film evaluation, and negative or intermediate film evaluation. Performance characteristics of interest for a color densitometer include total and operational density range, measuring geometry, linearity, drift, noise, precision and accuracy.

The density range must be sufficient to assure satisfactory operation with specified filters. Measuring geometry and linearity are of importance to problems other than process control. Good precision implies freedom from noise and drift. Precision is of particular importance in process or printer control. Accuracy is of importance in making intercomparisons with other instruments and for film evaluation purposes.

Satisfactory routine operation of a densitometer is best obtained by means of routine operating checks, maintenance checks, and performance checks. Performance checks may be made using plaques of film or other suitable materials. The plaques may be calibrated to provide precision or accuracy performance checks. Daily checks should be plotted on control charts and may be summarized on long-range trend charts. The controls may also be combined into a single "go no-go" gauge.

Until a few years ago, visual methods of evaluation were used for the control of printing and processing of color films. Color densitometers, which are instruments for measuring optical densities of the dyes deposited in processed color films, were introduced to replace the less reliable visual methods. It is the purpose of this paper to describe the important characteristics of direct-reading color densitometers and the methods which practical experience has proved to be satisfactory in controlling them.

Detailed discussion of densitometer design and basic principles of densitometry are given in references 1 and 2.

Types of Transmission Color Densitometers

Visual densitometers were the first type used for measuring the transmission densities of color films. The low precision and limited operational density range associated with visual densitometers restrict their usefulness.

Physical densitometers were designed to improve precision and to lessen the human fatigue factor. A physical densitometer depends upon a photoreceptor rather than the eye as the light-responding device.

Null densitometers have inherently the best design because they do not depend on linearity of response of the photoreceptor or the amplifier for their precision and accuracy. In this type of densitometer the light beam is split, and intensities of the two light signals detected by the photoreceptor or photoreceptors are matched by an optical attenuating device in either the sample or the comparison beam.

In the constant-signal densitometer only a single beam is used. A light attenuator is progressively removed from the beam, after the sample is inserted, until the signal returns to the same level as was originally obtained without the sample.

In the direct-reading densitometer, output of the photoreceptor and its amplifier is assumed to be linear. Sample density is determined directly from the photoreceptor output.[2] Direct-reading densitometers, the most common and the simplest in design, are the primary subjects of this paper. Most of what is said, however, applies equally well to the other types of densitometers mentioned above.

The Eastman Electronic Densitometer, Type 31A,[3] is a modern, direct-reading color densitometer which is suited to the control and evaluation of film printing and processing. Data obtained with these instruments will be used as examples.

Characteristics of Direct-Reading Color Densitometers and Their Evaluation

A number of characteristics of a direct-reading color densitometer must be taken into account in ascertaining the extent to which it can be employed for any given purpose. No system of analysis of these characteristics gives mutually exclusive categories. For convenience, however, they may be considered in terms of photometric, spectral and operational characteristics.

Photometric Characteristics

Photometric characteristics of a densitometer are largely inherent in its design. Both optical and electrical features of the design are of consequence. The two photometric characteristics which generally are of greatest importance may be termed *measuring geometry* and *total density range*.

Measuring geometry pertains to optical and geometrical characteristics of the beam of light incident on the sample and of the light collected from the sample. In the Eastman Electronic Densitometer, rays of light strike the sample within 10° of normal incidence, as shown in Fig. 1. This angle meets the American Standard recommendations[4] for measurements of diffuse transmission density. The photosensitive surface is at the end of the phototube and is practically in contact with the sample. Consequently, the acceptance angle on the emerging side is large. For silver photographic images, which have relatively high scattering power, readings approximately one percent higher than American Standard diffuse densities are obtained. Materials of lower scattering power, such as color films, show smaller departures from the American Standard recommendation.

Readings made on both diffusing and nondiffusing materials provide a simple operational test for the geometrical characteristics of a densitometer. With, for example, Kodak Wratten Neutral Density Filters No. 96,[5] as the nondiffusing material, and a photographic silver image as the diffusing material, readings of a series of densities on each of these materials are obtained on a densitometer. The density values for each type of material are plotted against diffuse densities as obtained on an instrument meeting the American Standards, as shown in Fig. 2. The ratio of the slope of the best straight line for the silver images to that of the Wratten

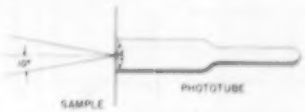


Fig. 1. Rays of light, in the Eastman Electronic Densitometer, strike the sample within 10° of normal incidence. The acceptance angle on the emerging side of the sample is large.

This paper is a combination of two papers presented orally on October 22, 1954, at the Society's convention in Los Angeles. The earlier forms of the papers were by the same authors and were entitled "Color Densitometers: Performance Characteristics," and "Color Densitometers: Control Methods." The authors are members of Color Technology Div., Eastman Kodak Co., Rochester 4, N. Y.
(This paper was received on May 12, 1955.)

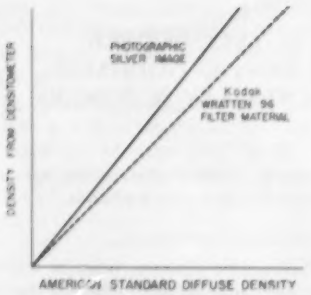


Fig. 2. Densities of a photographic silver image and of a Kodak Wratten No. 96 filter material measured on the Eastman Electronic Densitometer, as functions of ASA diffuse density (schematic).

No. 96 filter materials is called the measuring geometry index. This index is indicative of the geometrical characteristics of the densitometer. For Eastman Electronic Densitometers this index is about 1.01 to 1.02. For instruments which conform less well to diffuse density standards, the ratios would be larger. Usually, a densitometer which employs an integrating sphere, an end-on type of photoreceptor or an opal glass will meet the requirements of diffuse-density standards. A color densitometer having a measuring geometry index of 1.03 or greater will significantly change the densitometry of some color films.

Density readings of the standard diffuse type, rather than specular or doubly diffuse, are preferable for almost any kind of densitometry (ref. 2, pp. 186 ff.). For printing-density measurements made on a negative which is to be contact printed, standard diffuse densities are particularly desirable because the conditons of measurement simulate the conditions of use. Optical printing and projection conditions depart somewhat from the diffuse density measurement conditions. Even for such applications, however, diffuse density measurements are preferred. As shown in Fig. 3, small

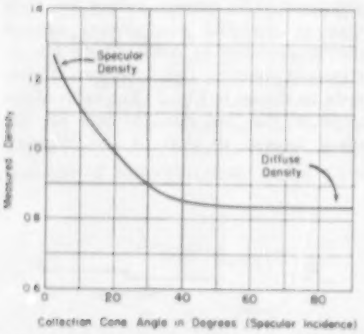


Fig. 3. Measured density as a function of collection cone angle, with specular incidence, showing the effect of measuring geometry on density measurements of a light-scattering film patch.

angular departures from optimum geometrical measuring conditions give smaller errors for diffuse measurements than for specular measurements (ref. 2, pp. 186 ff.). Specular densities are best obtained by calculations from diffuse density measurements.

Matching density readings from different densitometers can most easily be obtained if the instruments are designed to read diffuse density. For process control, if inter-instrument comparisons are not made, geometrical characteristics of the densitometer are not critical. For many types of film evaluation or printer control work, the specularity characteristics of the densitometer may be critical. This is especially true if more than one densitometer is involved.

The second important photometric characteristic, *total density range*, is determined with all filters removed from the light beam, except the heat-absorbing filter. Total density range depends upon the sensitivity of the densitometer and is the range of densities from zero to the maximum usable density capable of being measured by the densitometer. Usable densities are those that can be measured with acceptable precision and accuracy. Total density range is established by placing increasing amounts of nondiffusing neutral filter materials in the beam until the meter needle reaches an upper limiting value, or until the needle fluctuation becomes excessive. In terms of precision density measurements, density of the filter stack indicates the total density range. In establishing the range, meter needle fluctuations greater than ± 0.01 density are considered excessive. Amplifier gain adjustments may be made to minimize the fluctuations. Determination of the total density range of a densitometer is illustrated in Fig. 4, where a range of 0 to 7.1 density is indicated. Eastman Electronic Densitometers have total density ranges varying from about 0–6.8 to 0–7.2 depending upon the sensitivity of the particular phototube and the condition of the amplifier. A total density range of this magnitude is an optical-electrical problem of signal-to-noise ratio and can be met in any of the basic types of photoelectric densitometers.

In processing control and print film evaluation, a high total density range makes possible the employment of filters with narrow spectral transmission bands having high effective densities. The narrow bands of these filters minimize the effects of any spectral changes in photoreceptor and light source. High total density ranges are generally less essential in measuring printing densities.

Spectral Characteristics

Spectral characteristics of a color densitometer are determined by the

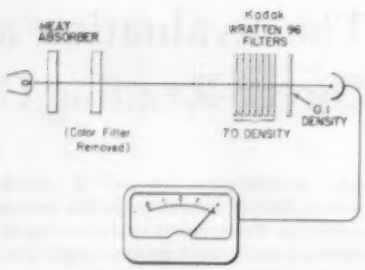


Fig. 4. The total density range of a densitometer is determined by the maximum density which the instrument can measure. The figure illustrates a total density range measurement of 7.1.

spectral sensitivity of the photoreceptor, by the spectral emission of the light source, and by the spectral transmittances of the color filters. The photoreceptor must have adequate response in the red, green and blue spectral regions. Phototubes with a photosensitive surface of the S-4 type are generally employed. For such a phototube the response of the densitometer is higher in the green than in either the red or the blue spectral regions. Adequate response in the red is generally the most difficult to obtain, even though a tungsten lamp with a high red-to-blue ratio of radiant energy is used as the light source.

Filters most frequently employed in densitometers used for measuring dye densities of color film are those which transmit only a narrow band of wavelengths which lie near the absorption maxima of the dyes of the color film. In some cases they are designed so that the spectral responses of the densitometer will match as well as possible the spectral responses of some particular print film. This design results in readings which approximate printing-density values.[6]

For the narrow band filters, standards have been adopted by the American Standards Association for the measurement of spectral diffuse densities of three-component subtractive color films[7]. Figure 5 shows the spectral density dis-

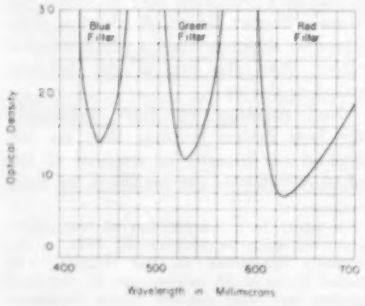


Fig. 5. Optical densities as functions of wavelength for the set of three filters most commonly used with the Eastman Electronic Densitometer.

tribution curves of the glass-gelatin color filters most frequently used with the Eastman Electronic Densitometer. Use of interference filters with the spectral densities shown in Fig. 6 has also been suggested;[9] these interference filters would comply with the ASA Standards.

Critical selection of filters to have the required spectral characteristics and maintenance of such filters to meet established standards are highly essential. The spectral requirements of the photoreceptors are less severe, and relatively wide spectral tolerances may be used in their selection.

Operational Characteristics

Important operational characteristics of a densitometer include *operational density range*, *drift*, *noise*, *linearity* and *interrange alignment*.

Related to the color characteristics of the densitometer is *operational density range*. This is the range of usable densities which can be measured through a given color filter. Operational density range may be measured by inserting Wratten No. 96 neutral density filters of known density into the measuring beam to obtain the highest possible reading on the densitometer, with needle fluctuations no greater than ± 0.01 density. A range of 0 to 4.0 through each color filter is desirable for many applications of color densitometers. For example, color print films usually have densities as high as 4.0. Picture areas of such high densities are not of great visual interest because they appear essentially black even though the dyes in these areas may depart significantly from neutral color balance. These high density regions are sensitive to slight departures from normality in processing and are therefore useful in processing control work.

Densitometer *drift* is related mainly to phototube stability and to amplifier stability. Phototube stability is often measured in terms of a light-drift and a dark-drift test. These tests are carried out by making intentional changes in the amount of light falling on the phototube and then returning to an initial reference light level. These drift tests thus separate phototube stability from amplifier stability since amplifier drift is not generally associated with optical factors.

When light-drift determinations are to be made, a sample of about 1.2 density is placed in the red* measuring position. Following a five-minute wait, during which the phototube approaches equilibrium, a reading is taken. The sample is removed for exactly one minute, then replaced; the departure from the original reading is immediately noted.

For testing dark drift, the 1.2 density sample is left in the red measuring position, and the phototube is again allowed five minutes to approach equilibrium. An opaque sample is then placed over the 1.2 density sample. After exactly one minute the opaque sample is removed and the departure from the original reading of the sample is immediately noted.

For the Eastman Electronic Densitometer the change in readings for either of these tests is generally less than 0.02 density units. These tolerance limits are achieved by using selected phototubes. The Eastman Electronic Densitometer also has a comparison optical beam to stabilize the amplifier and lamp.

A densitometer must be reasonably free from drift for any type of application. Care should be taken to insure that intense light does not reach the phototube. The phototube should be allowed sufficient time to "bake in" at normal light levels. Frequent rezeroing of the instrument will also help to eliminate effects of drift.

Electrical "*noise*" is another operational characteristic of a densitometer. Such noise may be detected by excessive meter-needle fluctuations. As previously indicated, noise limits the total density range of the densitometer. Electrical noise can be minimized by proper maintenance.

Linearity is a measure of the extent to which uniform increases in density of samples give uniform increases in density reading. This determination is made by reading a number of samples of known densities and plotting the readings against the known densities. For a simple test, measured densities are plotted against calibrated densities, and the best straight line through these points is drawn. Nonlinearity is shown by deviations of the points from the straight line. Figure 7 is a plot of linearity test data.

Some direct-reading densitometers, such as the Eastman Electronic Densitometer, are multirange instruments on which the scale covers a density range of only one unit of density. A range switch allows the instrument to read, successively, ranges from 0 to 1.0, from 1.0 to 2.0, from 2.0 to 3.0 and from 3.0 to 4.0.

A sample which reads exactly 1.00 in the lower scale range should give a meter needle reading of exactly 0.00 in the next higher range on such an instrument; otherwise, the densitometer has improper *inter-range alignment* or continuity. This difficulty is one form of tracking error which can occur on multirange instruments at the ends of the scale and which contributes to the nonlinearities of the densitometer. The inter-ranging characteristics of such a densitometer may be determined by means of a film strip which gradually increases over its length from densities less than 1.0 to more than 3.0. The low

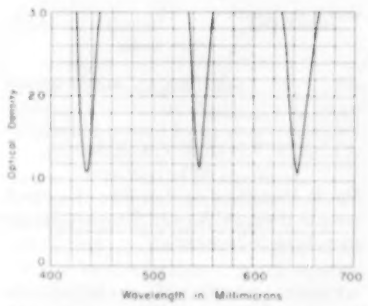


Fig. 6. Optical densities as functions of wavelength for a set of three interference filters.

density end is placed in the reading position. With the densitometer range switch set for the 0.0 to 1.0 density range, the strip is slowly advanced until a reading of exactly 1.00 is obtained. The reading is then taken on the next higher range using the range switch and the tracking error is noted. The same procedure is repeated at the 2.0 density level and at the 3.0 density level.

Departures from linearity, including those associated with poor inter-range alignment, are generally within the limits of ± 0.01 density on the Eastman Electronic Densitometer. Good linearity, which means good tracking throughout the entire operational density range, is essential for film evaluation work. Good inter-range alignment is essential for processing control, but linearity in its other aspects is not as important provided the readings are repeatable.

Electrical or mechanical failures can cause intermittent instabilities. These instabilities for the most part may be controlled by routine preventive maintenance.

In addition to the characteristics which have been discussed, accuracy and precision of a densitometer must also be considered. They will be discussed in conjunction with densitometer control procedures.

Control of Color Transmission Densitometers

Color densitometers used for film processing control must provide meas-

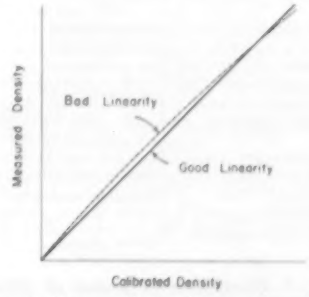


Fig. 7. Measured densities as functions of calibrated densities indicating good linearity and bad linearity (schematic).

* Drift tests are generally made through the red filter because thermal effects on drift are usually greatest through this filter.

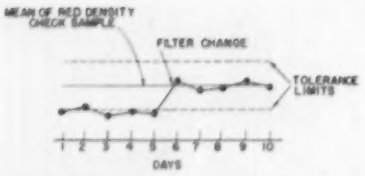


Fig. 8. Plot showing densities of a check sample through the red filter on successive days (schematic).

urements with known repeatability or precision. They are also used for film evaluation in terms of its visual characteristics, and for negative or intermediate film evaluation in terms of its printing characteristics. In these latter applications color densitometers must also be accurate. For optimum performance, a carefully planned densitometer control program is necessary if the instrument is to do the best possible job in reducing costs and improving quality of the color film processing and printing operations.

For example, to establish a film processing control program it is necessary to determine the inherent variability of the photographic process. This is accomplished by means of a densitometer which measures the densities of successively processed sensitometric strips. The density variations among strips which will be significant in determining control limits of the film process may be of the order of ± 0.03 density. Such a study of the process will lack meaning unless the densitometer variability is of a smaller magnitude. Control methods have been devised which will show how well a densitometer meets such a requirement.

Instrument performance checks fall into two general classes. These are spectral checks and photometric checks.

Spectral Checks

Spectral checks provide a measure of the spectral variations resulting from the combined effects of the components of a color densitometer. These characteristics include the sensitivity of the photoreceptor, the absorptions of the filters, and the emission of the light source. Spectral checks are generally made through colored check samples using each of the filters.

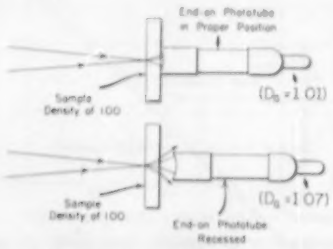


Fig. 9. Illustration of source of differences in density reading which may result from movement of phototube with respect to sample.

An example of a spectral departure from normality on an Eastman Electronic Densitometer is given in Fig. 8. Readings of a check sample through the red filter were out of control for several days. An investigation showed that the red filter was no longer standard. Replacement of the red filter after the fifth day brought the red density readings of the check sample into good control. Density checks through other filters were not affected.

Photometric Checks

Measuring geometry is one of the photometric characteristics of a densitometer which requires special checking. As stated before, a photographic silver image is relatively highly scattering; checks made through any one of the densitometer filters using a calibrated silver film will provide a check on the measuring geometry of the densitometer. These geometry checks are of particular importance when the densitometer is used to read silver or black-and-white film routinely. Measuring geometry is also relatively important for color film densitometry since some of the dye deposits are fairly highly scattering.

An illustration of a possible source of a measuring geometry error is given in Fig. 9. The normal position of the phototube in the Eastman Electronic Densitometer is shown in the upper part. A standard silver film sample with a diffuse density of 1.00 read 1.01 when the tube was in the normal, near-contact position. When the tube was inadvertently withdrawn a few hundredths of an inch, as shown in the lower part of the figure, the same sample read 1.07.

Measurements of silver film at approximately 1.0 density below the top of the operating range will minimize other errors and provide a sensitive check of measuring geometry. The green filter is frequently used because it is usually more stable than other filters, thus making the photometric check of measuring geometry more nearly independent of the spectral checks.

Periodic measurements of a non-scattering, nonselective film having high density serve as a photometric check on variables other than measuring geometry. Measurements near the top of the density range provide the most sensitive photometric checks since at this point the electrical signal is nearest to the noise level. In most densitometers a photometric shift will occur when the amplifier becomes noisy. As shown in Fig. 10, the readings of red, green and blue densities at the high end of the scale of a sensitometric film strip were depressed when the strip was read on a densitometer with a noisy amplifier. When the amplifier was repaired the high density readings returned to their expected values. Photometric aspects of densitometer control are particularly shown in the high density measurements made through all three filters. Variations in photometry cause similar deviations in all three high density checks, whereas a spectral variation would usually result in a deviation through only one of the filters.

A control check method which has been generally used for the control of Eastman Electronic Densitometers has involved daily readings through patches of color film. This film is mounted between plates of glass for protection. Such a plaque has the advantage that the film patches are representative of the types of materials being read routinely on a densitometer. Thus, when two types of film are read on the same densitometer, two different check plaques are generally used to make the control checks. Deviations detected by these checks are intended to be indicative of the deviations actually encountered in reading normal film strips.

A disadvantage of such a check plaque is that the dyes in color films are slightly unstable. Over a period of time and under adverse conditions, film check plaques may fade enough so that a densitometer appears to be out of control when it is actually providing reasonable measurements.

Precision Control

For certain work such as processing control, a densitometer need only read a given sample the same from day to day. That is, the densitometer's precision must be controlled.

The check plaque used for control of precision may be calibrated by making measurements of the plaque on the densitometer with which it is to be used for at least twenty consecutive working

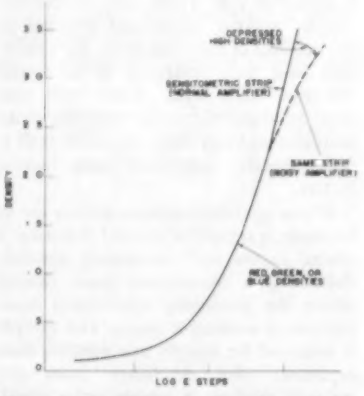


Fig. 10. Densities as function of log exposure on a sensitometric strip as read with a densitometer having a normal amplifier and with one having a noisy amplifier.

days. During this base period, the instrument should demonstrate stable operation. If alterations are necessary, such as replacement of a photoreceptor or a filter, the readings for the calibration period should be started again after the densitometer has returned to stable operation.

Base-period measurements should preferably be made at a random time during each day to prevent biasing the base-period data by possible systematic daily drift characteristics. Before taking any of these calibration measurements, the densitometer should be properly warmed up and carefully zeroed, and any adjustments normally made by the operator, such as inter-range alignment, should be checked.

The data representing checks made for at least twenty operating days are averaged. These averages are the precision control levels for that check plaque on that instrument.

Accuracy Control

When densitometers are to be used interchangeably, data from different instruments are to be compared, or a densitometer is to be used for measurements of any kind which can be defined independently of the instrument (such as printing densities), the densitometer's accuracy must be checked. The check plaque in this case must be calibrated so as to conform to accepted standards. These calibration values, rather than base period average values, establish the control levels in the accuracy check.

The calibrations are made on a standard instrument or are determined in some manner which is accepted as standard. For example, when several densitometers in one laboratory are used interchangeably, the average reading for all densitometers taken for several days might be considered standard. Deviations from standard levels measure the densitometer's lack of accuracy.

Control Charts

A record of each instrument's operation is maintained by means of a daily control chart. A daily control chart should be drawn for each densitometer. On a typical control chart, time in days is plotted along the abscissa, and check readings are plotted along the ordinate. Precision and accuracy control charts are alike except that the control levels are established differently.

A precision or accuracy control level is drawn in as a solid horizontal line on the chart. The chart has little value until control limits are also shown. Control limits indicate when a check reading is "in-" or "out-of-control." An out-of-control reading differs from the control level by more than a normally expected amount. This amount may be determined from the variability found in the twenty-day base-period data described above.

Control limits for precision checks are usually established by calculating the standard deviation, σ, for the twenty daily readings for each check. Methods for calculating control limits are described in the ASTM manual.[9] Such control limits are drawn as horizontal dotted lines at $\pm 3\sigma$ above and below the control means. When a daily reading falls outside the control limit, the densitometer has varied significantly more than it did during its twenty-day base period, probably because of an assignable cause.

Usually, the cause of such a significant variation should be eliminated before the densitometer is used again for routine work. Practical considerations, however, may dictate the adoption of other criteria. If the amount of variation allowed by these $\pm 3\sigma$ limits is too great to be tolerated in the intended use of the densitometric data, the major causes of the variability will have to be identified and eliminated. That is, densitometer improvements must be made. On the other hand, if the normal precision of the instrument is more than adequate, wider limits are justified.

The control limits used for the precision checks should be satisfactory for the accuracy checks if the instrument does not, on the average, read differently from standard (i.e., the instrument is unbiased). Any bias should be eliminated by improving the densitometer. Bias can be taken into account when it has been reliably measured. However, replacement of any major component of the densitometer is likely to change the bias.

The bias of the densitometer may be determined by averaging the daily checks over some interval such as a four-week period. These averages, for successive periods, may be plotted on a long-range trend chart. In addition to showing the instrument's average bias for any particular period, these charts quickly show any long-range trends in the instrument readings.

To establish the bias or long-term changes in instrument reading characteristics it is necessary to make certain that check plaque fading is not affecting the readings. If an instrument shows "out-of-control" on its long-range plot, readings on a second, newly calibrated plaque are usually made before instrument maintenance is undertaken.

Chi-Square Control

A technique of combining several independent checks made on a densitometer into a single "go no-go" gauge has proved to be very convenient. A single control number, called Chi-square, is arrived at by two steps.

The first step is to square the deviation of each individual check from its control level, and to divide this squared deviation by the variance, sigma squared, for that check. This ratio is called "t." In practice, these computations are avoided by setting up tables which list values of "t" for an appropriate range of check readings.

The second step is to add these t's. This sum of t's is called "Chi-square." A control limit is set for this Chi-square, which will be exceeded by chance only for a certain percentage of the checks. For example, in the film check plaque described above, which is used within the Eastman Kodak Co. for controlling Eastman Electronic Densitometers, a Chi-square limit of 22.5 is used. Since six readings comprise a single daily set of checks, the limit of 22.5 will be exceeded by chance only one time in a thousand, provided that the checks are mutually independent, that true means and variances are used, and that the densitometer variations are random. When a Chi-square greater than 22.5 is encountered, the instrument is not used again until maintenance has brought the instrument back into good control.

The procedures and methods described in this paper are a summary of several years' experience of the Densitometer Control Center of the Color Technology Div., Eastman Kodak Co.

References

1. Color Sensitometry Subcommittee Report, "Principles of color sensitometry," *Jour. SMPTE*, 54: 655-724, June 1950.
2. R. M. Evans, W. T. Hanson, Jr., and W. L. Brewer, *Principles of Color Photography*, p. 406 ff., John Wiley & Sons, New York, 1953.
3. K. G. Macleish, "Transmission densitometer for color films," *Jour. SMPTE, 60:* 696–708, June 1953.
4. Diffuse Transmission Density, American Standard Z38.2.5-1946, American Standard Assn., 70 E. 45 St., New York 17.
5. *Kodak Wratten Filters*, 18th Ed., Eastman Kodak Co., 1951.
6. F. C. Williams, "Objectives and methods of density measurement in sensitometry of color films," *J. Opt. Soc. Am., 40:* 104–112, 1950.
7. Spectral Diffuse Densities of Three-component Subtractive Color Films, American Standard, PH 2.1-1952, American Standard Assn., 70 E. 45 St., New York 17.
8. E. K. Letzer and S. A. Powers, "Interference filters for photographic densitometry," *J. Opt. Soc. Am., 44:* 870–874, Nov. 1954.
9. *ASTM Manual on Quality Control of Materials*, American Society for Testing Materials, Philadelphia, 1951.

Method for Evaluating Potential Efficiencies of Incandescent Light Sources for Slide Projectors

By J. A. Van den BROEK

For the designer of projection equipment to make an intelligent choice from among the many available projection lamps, some performance data not ordinarily supplied by the manufacturer may be of value. Apparatus and a method have been devised by which the performance of lamps can be measured and evaluated in terms of their potential efficiency when used in a projector.

Projection lamps, the common light source for slide projectors, are made available by their manufacturers in considerable variety. They range from less than 100 w to more than 1500 w. Lamps of the same wattage are often available in different bulb sizes and shapes, and in the same wattage and bulb there is sometimes a choice of filament type. Furthermore, otherwise identical lamps are sometimes available with a choice of design life and consequently different performance. The majority of the filament types used fall into one of three categories; the 2CC8, the C13 and the C13D (Fig. 1). Since each of these filament types has its own performance characteristics, the number of different lamps available to the projector designer is considerable. Generally the only performance data supplied by the lamp manufacturer is the approximate total initial lumens and the expected average life of the lamps. For one who must choose the light source most suitable for a proposed projector design, these data alone are not sufficient to make the most intelligent choice.

Filament Types and Performance

The projector designer's primary concern is usually how to obtain the highest possible level of screen illumination, consistent with definite factors of quality, for a given wattage. It is readily apparent that the initial lumen figure is not much help in predicting a lamp's performance in a projector since it is based on the total emission in all directions, while only part of the emission can be used. For example the total lumens are measured before the application of an opaque coating on top of the bulb. While the addition of the opaque top has little or no effect on the projector performance of the lamp, it does affect the total lumen figure. Also, two lamps of the same wattage and total lumen performance may have different filaments and perform quite differently in a projector.

Generally, projection lamps emit light in all directions but only that part of the emission that is contained in a solid cone with an angle of about 90°, with its apex on the center of the filament and its axis coincident with the axis of projection, can be used. If the light source were to radiate equally in all directions this use would amount to only about 15% while the remaining 85% serves only to heat up the projector. Consequently lamp designers endeavor to construct lamps that emit a higher percentage of their total output in the direction of projection. Since it is in effect the surface of the filament that emits the light, one step in this direction is to design the filament in such a way as to increase the percentage of filament surface that is exposed to the condenser optics. This is accomplished with varying degrees of success with the filaments mentioned which feature two or more coils of filament wire arranged in a plane normal to the projection axis. How this affects the light distribution is shown in Fig. 2.

The next step toward greater use of the light produced is to put a spherical reflector behind the filament which will re-image the filament on itself and return to the front of the lamp some of the light contained in the rear cone that would otherwise be lost. This reflector

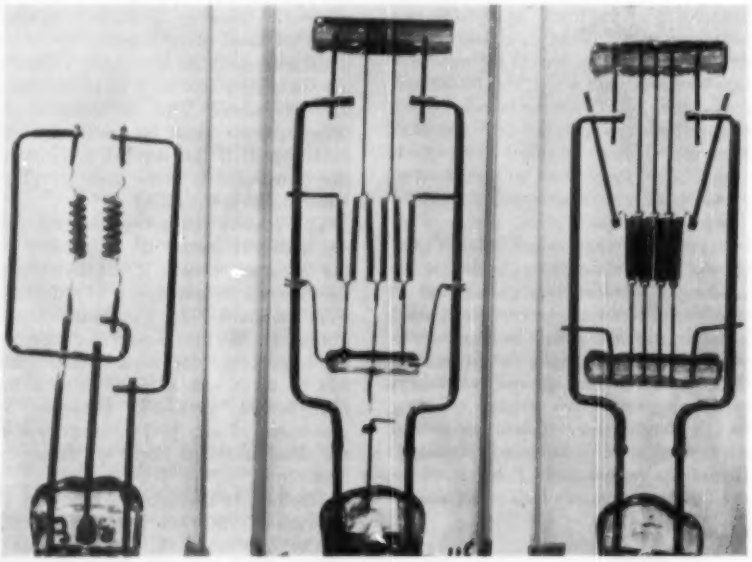


Fig. 1. Three common types of projection lamp filament construction, from left to right: 300-w 2CC8, 500-w C13 and 500-w C13D.

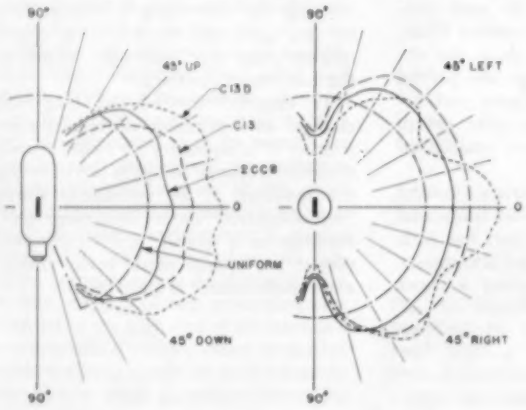


Fig. 2. Light-distribution curves on the horizontal and vertical planes coincident with the projection axis for three different filaments and a uniform source. All curves are scaled to the same total lumens.

Presented on April 22, 1955, at the Society's Convention at Chicago by J. A. Van den Broek, Argus Cameras, Inc., Ann Arbor, Mich.
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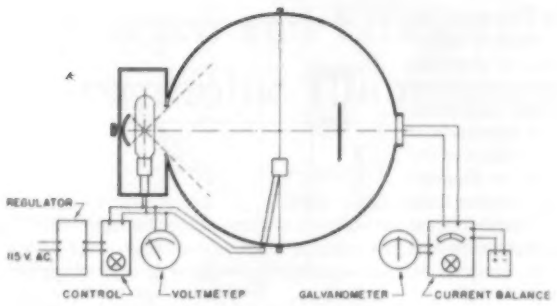


Fig. 3. Schematic of the apparatus.

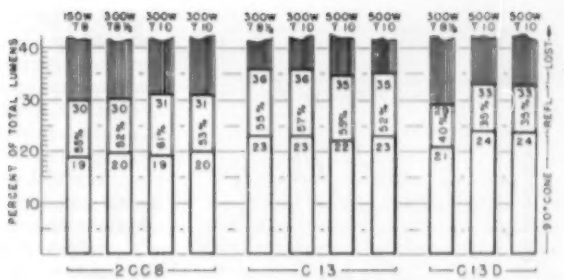


Fig. 4. Graph showing the percentage of the total light produced that is contained in a 90° solid cone on the projection axis, for three different filament types, and the light that can be added to that cone by a spherical reflector behind the filament.

may be part of the lamp, but at present it is usually a separate part attached to the housing in which the lamp operates. There appears to be little we can do to use the light lost outside the front and rear cones. The effectiveness of the reflector varies with the type of filament. The 2CC8 and the C13 filaments, which consist of two and four or more coils, respectively, arranged in a single plane, derive greater benefit from the reflector than the C13D biplane filaments.

In the monoplane filaments the coils are spaced by a distance approximately equal to their diameter, so that the filament image projected by the reflector on the filament plane can be arranged to fill these spaces and the reflected light can consequently pass on to the condenser and be used. In the C13D filament the coils are arranged in two parallel planes of three or four coils each so that the coils are staggered, and when viewed along the projection axis the filament area appears to be almost entirely filled with coils.

At the present state of the art this construction presents the greatest possible concentration of filament and several features of it make for high efficiency. However, the benefit from the reflector is considerably less with this filament because its coil concentration interferes with the passage of reflected light, and the reflector's primary function appears to be to increase the temperature of the filament and hence increase its light output somewhat. A great many details of lamp construction affect the efficiency in terms of lumens per watt, but these problems are primarily those of the lamp manufacturer and do not concern us as much as the use of as much as possible of the light produced and the inherent potential projector efficiency of the various lamp types.

Measuring Equipment

An attempt has been made to devise a means to evaluate the potential projector performance of a lamp and to measure the performance characteristics of the various types of filaments with and without a reflector, in terms of the percentage of the total lumens contained in a 90° solid cone on the projection axis. The device made for this purpose consists of a photometric integrating sphere with appropriate attachments, controls and measuring equipment (Fig. 3). On one side of the 24-in. diameter sphere is a 3½-in. diameter opening leading to an exterior lamphouse. A means is provided for closing the opening if desired.

The sphere consists of two halves, one of which is fixed while the other is attached by a hinge so as to permit access to the interior. The interior of the sphere has a flat white finish with a reflectivity of about 92%. The interior of the lamphouse is flat black. A medium prefocus lamp socket is provided in the center of the sphere and another similar socket is mounted in such a position in the lamphouse that the center of a standard lamp filament is at the apex of a 90° cone circumscribed by the aperture between the sphere and the lamphouse. Adapters are provided for bayonet base and medium screw base lamps.

A spherical reflector is adjustably mounted behind the lamphouse socket so that the center of curvature approximately coincides with the center of a standard lamp filament. Power to operate the lamps is regulated first through a Sola constant voltage transformer and second through a Sorenson regulator. Adjustment is provided by a Variac transformer and a low-resistance rheostat for fine adjustment.

A sampling of the light in the interior of the sphere passes through a small opal glass window in the side opposite the lamphouse to a Weston photoelectric cell equipped with a Viscor filter. Light-intensity readings are taken with a Rubicon current balance and a sensitive galvanometer. With this equipment it has been possible to establish projector efficiency factors for the different types of filaments. While to some extent these factors were merely verified because they were already suspected from measurements of actual projector performance, it is felt that, since many additional factors effect projector performance, the actual measurement of the light-source performance without the use of optics, is a basic requirement.

Results From Measurements

Figure 4 shows the results from measurements on eleven lamps, arranged in three groups by filament type. The last two columns in each group are measurements on different lamps of identical construction. The first group represents four lamps with 2CC8 filaments, the second group of four are C13 and the third group are C13D filaments. The lower section of each column represents the percentage of the total lumens that is contained in the frontal 90° cone. The second section of each column represents the percentage of the total lumens gained by the frontal cone by the use of the reflector in optimum adjustment. The lamps selected are representative of those most commonly used in their wattage group and are most readily available, with the exception of the 500-w T10 C13 lamps which were especially made for this purpose.

As Fig. 2 gave reason to suspect, it is evident that all projection filaments have a cone efficiency considerably better than a uniform source's theoretical 15%. The 500-w C13D lamps are the most efficient of those represented with a cone lumen of 24% of the total, without a reflector. Next in line is the C13 filament with a cone content of from 22 to 23% and least efficient is the 2CC8 with 19 to 20%. The reflector effect is about equal for the 2CC8 and the C13 filaments and ranges from a gain of 52% to 60% in cone lumens. It is notably less for the C13D where it adds between 35 and 40%. The total of cone plus reflector lumens in percent of the total emitted, or the projector efficiency factor, appears to be highest for the C13 at about 35%, second for the C13D at 33% and lowest for the 2CC8 at 31%. It is apparent that, while the C13D filament has a higher "front cone only" efficiency, it is second to the C13 for performance with a reflector.

While these results are somewhat less

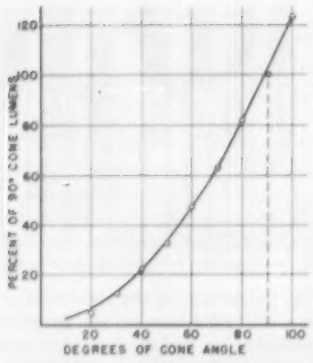


Fig. 5. Distribution of light (for various cone angles) as a percentage of that contained in a 90° cone.

than sensational because the efficiency differences are relatively small, they are nevertheless useful and of interest to the projector designer who is forever striving for a gain of a few percent in screen performance.

Another item of information of value to the designer is the distribution of light per degree of cone angle. While some idea of the nature of this distribution may be had from the graphs in Fig. 2, a more realistic figure can be obtained with the aid of the photometer. It is only necessary to use apertures of different sizes between the lamphouse and the sphere. The result, when plotted, gives a distribution curve as shown in Fig. 5. The curve appears to be substantially the same for the three types of filaments measured and for the angles covered. It shows that an increase in cone angle from 90° to 100° yields approximately 22% more light while a decrease from 90° to 80° reduces the useful light by about 18%. It is evident that the angle of the cone of light that is accepted and used by the optical equipment may have an important bearing on the overall efficiency of the projector.

Application of the Information Gained

The data presented by Figs. 4 and 5 can be combined into one graph such as Fig. 6 and show the actual available lumens (for various cone angles) for two or more different lamps of the same life and wattage. However, while a larger cone angle pays off in terms of available lumens, its use requires condenser systems of short focal length and high magnification, which in turn require objectives of large aperture. The magnification of the condenser and the size of the filament dictate the aperture of the objective and, while the objective focal length is generally fixed by performance requirements the relative aperture is limited by economic as well as physical factors.

With this limitation it may be more advantageous to use a less efficient lamp and a larger cone angle than a more efficient one and a smaller angle, as shown in Fig. 7a and 7b respectively. On the other hand, if a larger objective is no obstacle, both the larger cone angle and the larger and more efficient filament can be used to produce a more efficient projector, as in Fig. 7c.

If the focal length and the relative aperture of the objective are fixed by performance and cost factors, and the sizes of the available filaments are known the magnification of the condenser and the cone angle can be determined.

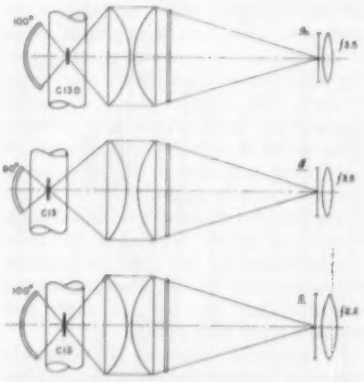


Fig. 7. Schematic diagrams of three hypothetical projector optical systems showing: (a) small filament, large cone angle and small aperture objective; (b) large filament, small cone angle and small aperture objective; (c) large filament, large cone angle and large aperture objective.

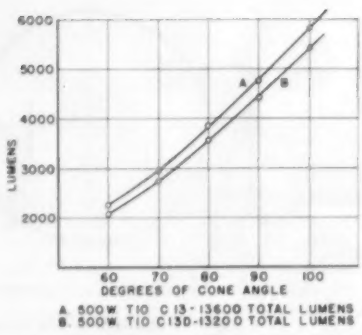


Fig. 6. Comparison of the total available lumens (with reflector) (for various cone angles) for two different filaments of the same wattage.

Since a curve such as shown in Fig. 6 can give us the lumens (for various cone angles) for the different filaments under consideration, the most advantageous choice can be made at this stage of the development and the rest of the system planned accordingly.

Other Uses of the Equipment

Other uses of the equipment include the calibration of lamps before testing a projector's optics for efficiency. While it is a simple matter to take screen illumination readings in accordance with ASA procedure, quite substantial inconsistencies may result from variations between supposedly identical lamps. For accurate information on the efficiency of the optics, the lamp used should first be calibrated or made to conform to a standard for its type. Such performance standards can be set on the basis of the total lumen figures published by the lamp manufacturer and the efficiency factor for the filament type as measured on the cone-photometer.

Acknowledgment

The author is indebted to the Lamp Division of the Westinghouse Electric Corp., to the Lamp Division of the General Electric Co. and to the Radiant Lamp Co. for their cooperation in supplying technical information and special lamps for this project.

A Rugged and Efficient High-Speed Photographic Illumination System

By J. M. NOVAJOSKY

This paper describes a test program which was conducted at the Allison Div. of General Motors Corp. in order to evaluate the performance of various incandescent lamps when operated at high voltages for high-speed photographic purposes. Lamp life, efficiency, color balance exposure and the design of an applicable power supply are also presented.

THE NEED FOR a rugged and efficient lighting system for use in conjunction with the high-speed motion-picture camera became evident prior to the acquisition of our present equipment at the Allison Div. of General Motors. The ruggedness requirements are paramount when we consider the fact that much of the high-speed photography work due in developing jet power plants is performed in hazardous areas such as the test stands and components test laboratory. Other handicaps are the presence of high-frequency vibration, buffeting in high-velocity air streams, extremes of temperature and generally rough handling on the job. Efficiency becomes a factor from the standpoint of reliability of operation, light output, power requirements and cost. It is with all of these factors in mind that we undertook a program to investigate the performance of various commercial lamps when used as lighting sources for our particular type of high-speed photography.

Figure 1 illustrates the four types of General Electric 120-v lamps which were evaluated at the time of our investigation. The lamp at the extreme left is the very familiar and rugged 150-w PAR 38/SP lamp which is being used by many as a high-intensity lighting source by operating at abnormal voltages. The next lamp is a conventional photographic spot, the 300 R/SP. The third lamp from the left is the PH 750-R bulb which had been designed for high-speed photographic purposes. The next lamp is a rather new type of bulb patterned after the automobile headlight. This 300-w PAR 56/SP is the lamp which was found to be best suited to our needs and is consequently the only one with which we will be primarily concerned in this paper.

Illumination Tests

Since high-speed motion-picture quality depends, to a great degree, upon availability of a sufficient quantity of light it was in this regard that we undertook a program to determine the light output of the lamps previously described. All illumination tests were performed in a darkened room with the lamp under evaluation being positioned on a tripod 10 ft away from a Weston No. 614 incident-light meter. Peak lamp intensity and polar distribution were obtained by laterally moving the meter through the equivalent of a 24° arc and obtaining light readings in 3° increments from center. Light readings were obtained in 10-v increments between 90 v and the burnout point of the respective lamps. Six samples of each lamp were tested in this manner, the data averaged and then plotted as shown in Fig. 2. A type 1226 Powerstat, operating from 220 v, was used as a variable-voltage source throughout the test program. Note the 5 : 1 ratio of PAR 56 lamp intensity of the familiar PAR 38 bulb at voltages 10% below their respective burnout points. The 3 : 1 intensity ratio between the PAR 56 lamp and the special high-speed photographic spot, PH 750R, 10% below burnout is also noteworthy.

Figure 3 illustrates the polar light distribution of three types of lamps at voltages 10% below their respective average burnout points.

The current consumption of each lamp was recorded and plotted in Fig. 4 to aid in determining the design requirements for the power supply to be discussed later. These data also served in computing the commercial efficiency of each lamp based upon the peak lumen output and current consumption. The efficiency data as plotted in Fig. 5 again illustrate why we are using PAR 56 lamps in most of our work.

Lamp Life

A frequently asked question when discussing overvoltage operation of incandescent lamps is, "How long will a bulb last when operated in this manner?" We decided that the best way to find the answer to this question was by actual test. A test machine was built to cycle automatically five of each of the bulbs being discussed in this paper. The bulbs were individually cycled by burning 15 sec at a voltage 10% below the previously determined burnout point and then turned off for a 45-sec cooling period. A photocell installed in the cycling circuit stopped an electric counter when a bulb failed to come on at the prescribed time. Figure 6 illustrates the life expectancy of these various lamps when operated at 10% below burnout voltage. The cost of operating any of these bulbs is small indeed when the results obtained are considered.

Color Balance

What about color balance of overvolted lamps? Since the PAR 56/SP lamp is the only one used in our high-speed motion-picture program we did not delve into this relationship with the other lamps. Generally it is not necessary to obtain a true color rendition of a high-speed subject but merely a variation in color so that motion of certain parts could be more easily studied. However there is a certain amount of self-satisfaction in getting pictures that

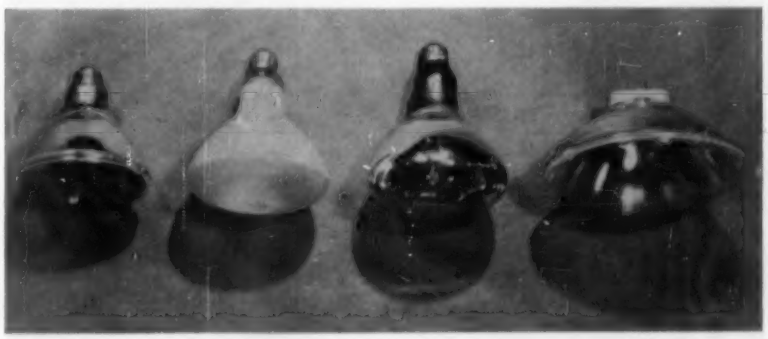


Fig. 1. Photograph of four lamps tested: left to right — 150 PAR 38/SP, 300 R/SP, PH 750 R, 300 PAR 56/SP.

Presented on April 21, 1955, at the Society's Convention at Chicago by J. M. Novajosky, Allison Div., General Motors Corp., Indianapolis 6, Ind.
(This paper was received on July 1, 1955.)

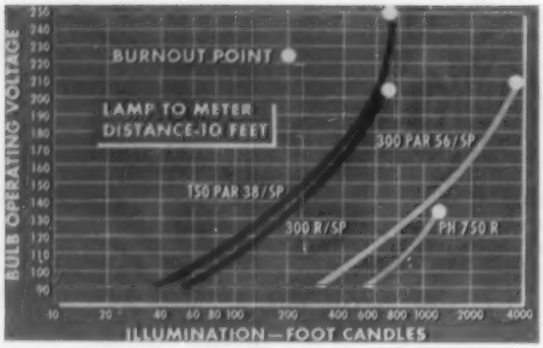


Fig. 2. Curve of peak light output of various overvolted G.E. lamps.

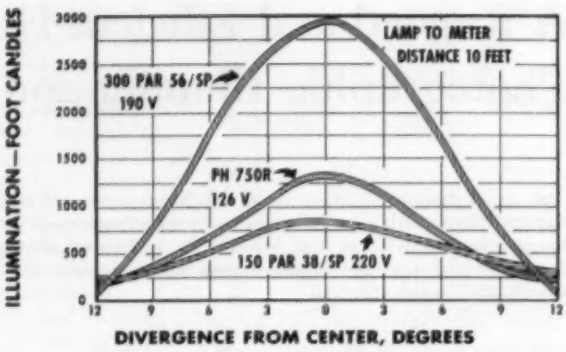


Fig. 3. Curve of polar light distribution of various overvolted G.E. lamps.

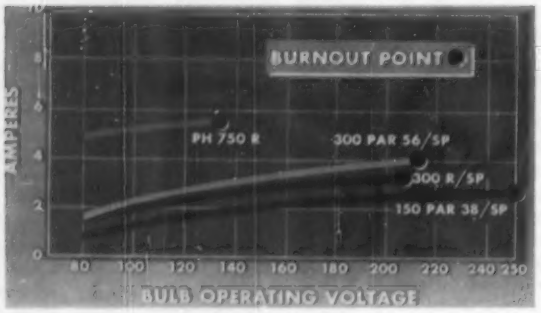


Fig. 4. Curve of current consumption of overvolted G.E. lamps.

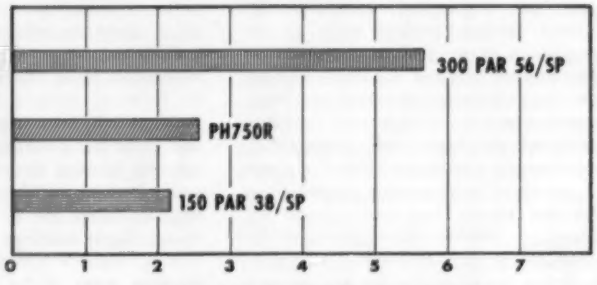


Fig. 5. Curve of peak commercial efficiency of various overvolted G.E. lamps.

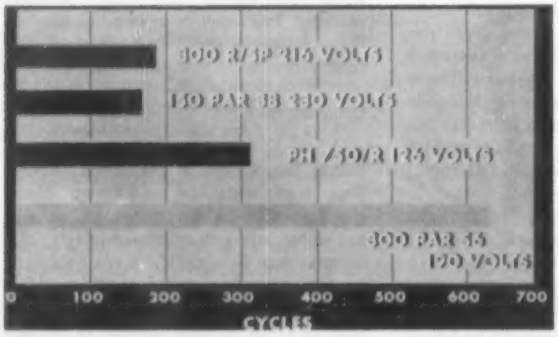


Fig. 6. Curve of endurance life of various overvolted G.E. lamps.

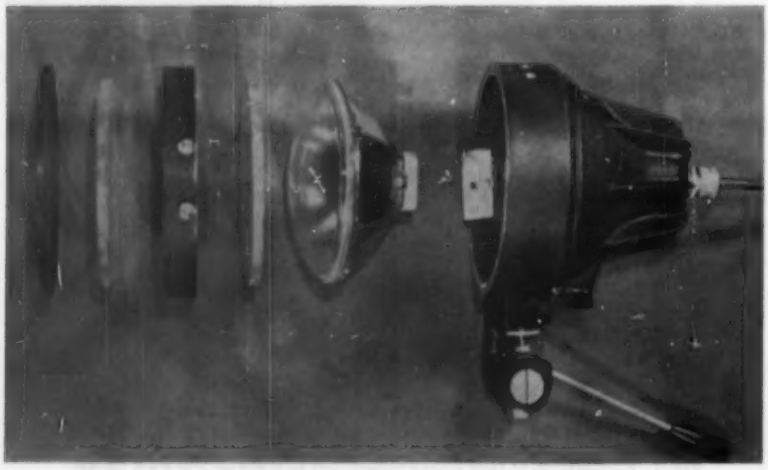


Fig. 7. Exploded view of lamp housing assembly.

look "right." A very limited program was conducted to determine the color balance of the PAR 56 lamp while operating in the 180-v range. A standard Kodak color test card was photographed on Type A Kodachrome using conventional photoflood lighting and also PAR 56 lamp illumination. Comparison of results indicated that the PAR 56 lamp is very well balanced for use with Type A Kodachrome when operated at 180 v, therefore no correcting filter is necessary.

Lamp Housing Design

Since standard PAR 56 lamp housings proved to be inadequate for our particular purposes, we designed a housing which could be pressurized for use in hazardous areas, incorporated a swivel-type mount and a water cell for heat absorption. Figure 7 shows the general configuration of the lamp assembly while Fig. 8 gives the details of construction. A Steber S-401 lamp housing was reworked to provide the features which we required, without appreciably increasing the cost of the unit. In many instances the standard Steber housing would be adequate, however.

Power Supply

Having determined that the power requirements of the high-speed camera, lights, pulse generator and related equipment are rather high, it was felt that operation of this equipment from 110-v lighting circuits would be unsatisfactory.

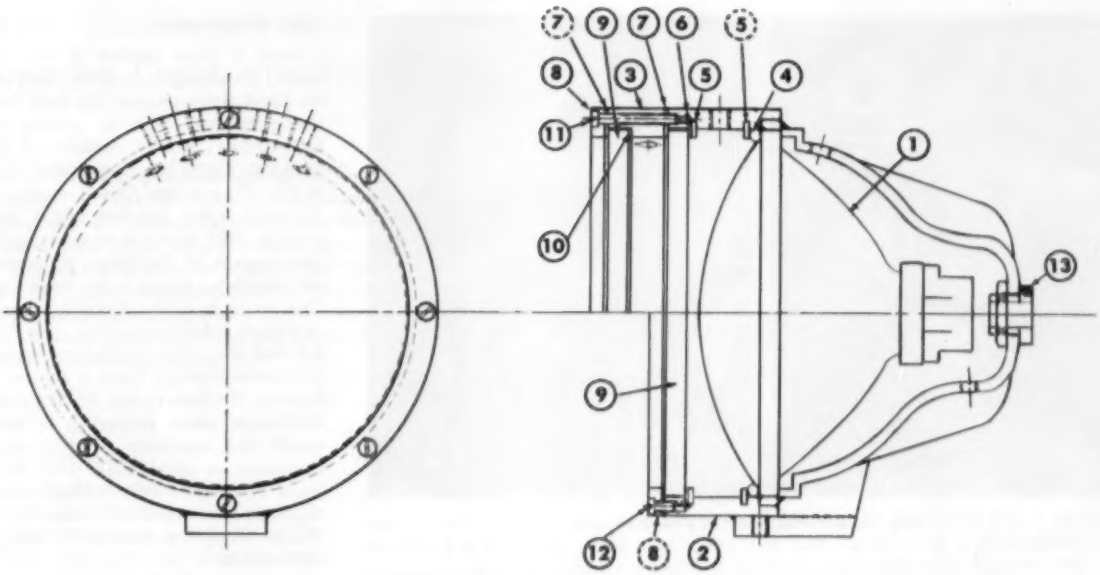


Fig. 8. Section drawing of lamp housing assembly.

After considerable deliberation, it was decided to design a power supply, capable of meeting our present and future requirements, which would operate from our 440-v, 3-phase, 60-cycle power system. The schematic shown in Fig. 9 illustrates the circuitry used to meet these needs.

Operation of the power supply is as follows. Power is fed into a General Electric 95G33, 5kva, step-down transformer. One half of the secondary coil output, or 110 v, is then fed into a bank of six receptacles which are always "hot" for use in operating the camera control, pulse generator and related equipment. The full output of the secondary, or 220 v, feeds the Powerstat Type 1226, 2.4 kva autotransformer. This autotransformer furnishes any desired voltage between 0 to 270 v to the ten PAR 56 lamp receptacles. The position of the double-pole double-throw mid-position off switch determines whether 110 v is applied to the lamp receptacles for focusing and lamp set-up or whether the predetermined high-voltage output from the autotransformer will be channeled to these receptacles through the relay at the time the switch is thrown to the "shooting position." A remote receptacle parallels the "shooting" contacts of the DPDT switch for operation at long range. Relay actuation can also be used to control the flow of d-c current through the power supply and also activate two 110-v receptacles if desired.

Although the Type 1226 Powerstat being used in this power supply is normally rated at 9 amps., 2.4 kva output, we have operated at an output of 6.8 kva or 280% overload when using 10 lamps for very short periods of time

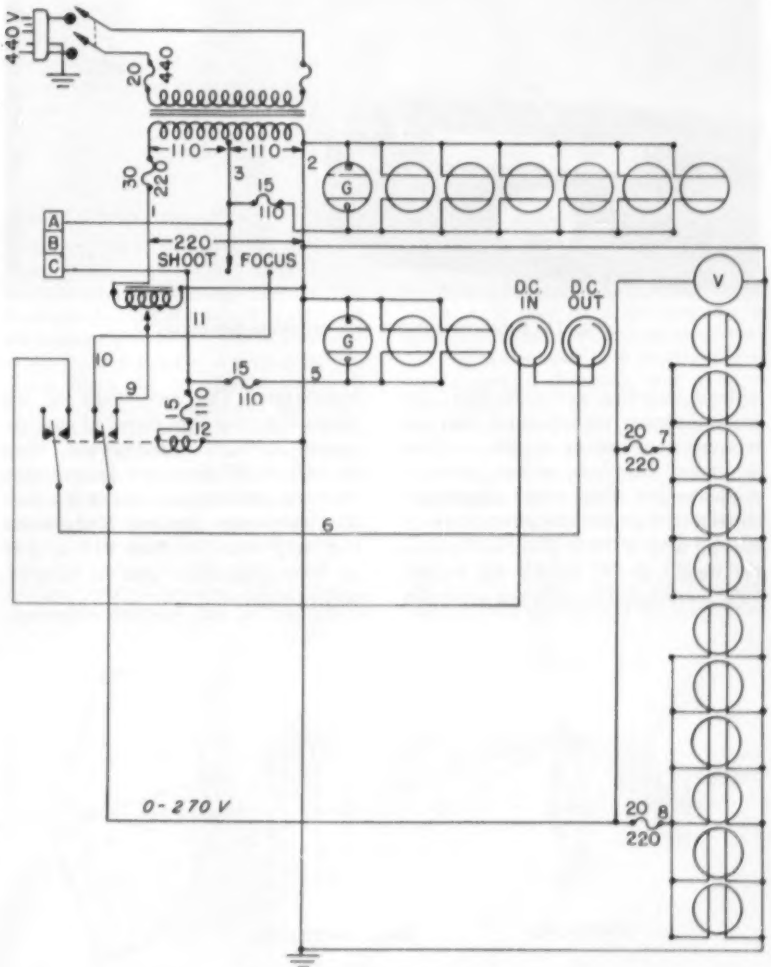


Fig. 9. Power supply schematic.

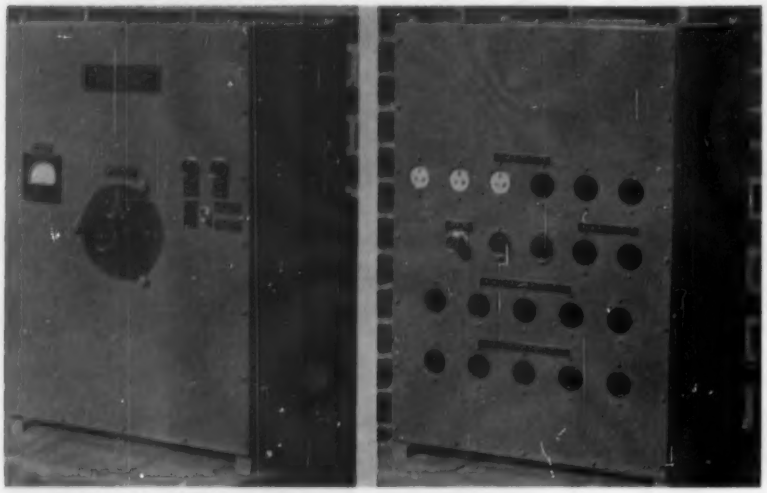


Fig. 10. External view of power supply.

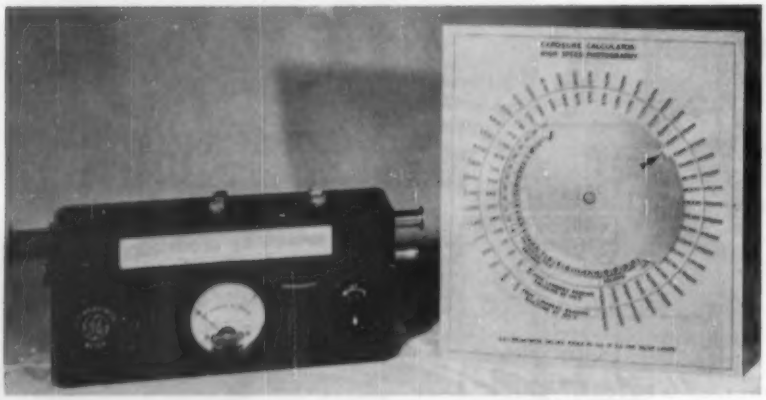


Fig. 11. Brightness meter and exposure calculator.

without incurring any difficulties. The autotransformer manufacturer does not recommend operating at this condition for more than one minute however. A photograph of the power supply may be seen in Fig. 10. The physical size of the unit is 12 × 18 × 27 in. and it has a net weight of 195 lb. Of this weight, 50% is attributed to the 5 kva step-down transformer. The end result of this design is a total light ouput of approximately 2,000,000 candlepower when 10 PAR 56/SP lamps are in operation. This is a sufficient amount of illumination to permit shooting Kodachrome film at *f*/4 or Du Pont 931 at *f*/16 at 8000 frames/sec with a lamp-to-subject distance of 3 ft.

Light Measurement

Since a great portion of our high-speed photography was to deal with the combustion process, the need for an unconventional type of photographic light meter became evident. A G.E. Luckiesh-Taylor brightness meter, shown in Fig. 11, was used in this application. Although this is not basically a photographic light meter it was adapted for that purpose by the design of the exposure calculator shown in the same figure. This meter is a visual type photometer calibrated in brightness units up to 50,000 ft-L and is capable of obtaining accurate brightness readings from a subject 500 ft away. Needless to say, this is a distinct advantage when preparing to photograph the operation of a jet-engine combustor or afterburner. After obtaining a reading of subject brightness the exposure is determined from the calculator which was designed by using the relationship:

$$f = \sqrt{\frac{TBI}{4.25}}$$

where: f = lens stop
T = exposure time, sec
B = subject brightness, ft-L
I = exposure index

When using the PAR 56 lamps, we obtain a reading of subject brightness with the lamp operating at 110 v. This reading is then set-off on the inner brightness scale. The outer scale merely indicates what the brightness will be at 180-v lamp operation. In so doing we minimize subject heating and extend lamp life.

The above described illumination system has been in use two years and in that time has performed better than originally expected. The ruggedness of the PAR 56 lamp is exceptional and the author would recommend consideration of this system of illumination by those who have requirements similar to ours.

The author wishes to thank Byron Dow of the Allison Photographic Dept. for his assistance during this evaluation and also for the excellent set of slides he prepared for the presentation of this paper.

Screen Illumination as Affected by Projection Lenses and Projector Optics

By JOHN R. MILES

Projector illumination is produced by one of two basic types of optical systems, the first being the True, or Classical, Condenser System, and the second, a Source-Imaging System. Theater motion-picture illumination is not produced by classical condensers, but rather by source-imaging systems, which have specific characteristics limiting the light on the screen edge. Some of these characteristics are often produced by using short-focus lenses with a mirror designed for long-focus lenses. This produces difficulties which are not completely overcome by faster lenses. Tube sizes and spaces in projectors, meant for long-focus lenses, also frequently produce uneven illumination.

Classical Condenser

The classical condenser system is shown diagrammatically on Fig. 1. In this case, the source is imaged by the condenser lens onto the objective lens, which, in turn, images the film close to the condenser onto the screen. In this way, the objective lens also images the surface of the condenser onto the screen, or nearly so, and this device produces almost perfect uniformity of illumination across the screen, regardless of the variation in brightness of the source across the face of the source.

In the example shown on Fig. 1, the condenser is the same size as the film, and the same size as the objective lens, while the source is smaller than either. In this particular case, it would appear that the speed of the condenser must be equal to the speed of the objective lens, but usually this requirement does not exist, as such, and other considerations control the size and speed of the condenser lens. In the case of this classical condenser system, the condenser does not increase the illumination on the center of the screen in any way, but simply brings the light bundles from the edge of the field around to pass through the objective lens.

The size of the condenser must be at least as large as the film aperture, and, usually, it is considerably larger in this type of system because it is placed at a slight distance from the film aperture. In many cases, the speed of the condenser must be as much as two or three times the speed of the objective lens. (Speed is defined as focal length of a lens divided by its diameter or free aperture.) Thus, a lens of 3-in. focal length with a 1-in. diameter has a speed of $f/3$. The magnification of the condenser is arranged so that the image of the source is equal in size to the aperture of the objective lens, and this image of the source must be formed in the objective lens stop to produce the even illumination required.

One of the several difficulties in using this type of condenser for professional motion-picture projection is that the condenser is too close to the source in most cases, and, in case an arc is used, the spattering from the arc damages the condenser too quickly.

Another difficulty is that the condenser must be of a very high speed in order to obtain illumination on the edge of the field.

A compromise of the true condenser is sometimes used in small movie projectors for 16mm and 8mm film, in which case the source is imaged between the objective lens and the film, while the condenser is closer to the source.

Source-Imaging Systems

In the source-imaging system the source itself is imaged or projected onto the screen, or other area to be illuminated. A simple example of this type of system is the military searchlight, where the crater of the arc is imaged at a very great distance. Since the searchlight mirror is rather long focal length, and the crater quite small, the beam is rather narrow and very intense. The professional motion-picture projector for 35mm film uses a source-imaging system, where the mirror (or condenser lens) images the source at the film gate, and the projection lens re-images this source, and the film gate, onto the screen. This system is convenient because the arc, which is usually used, has a fairly even brightness, and this method keeps the source at a considerable distance from the mirror and produces the proper magnification of source image without too much difficulty.

In the event the classical condenser system is used for a 6-in. $f/2$ lens, the magnification of the condenser would have to be three times as great and the mirror considerably larger in order to equal the performance in the center of the field as the mirrors are now used.

Standard Projector

The upper portion of Fig. 2 shows a normal mirror from a professional motion-picture projector, together with an example of a 6-in. lens and 2-in. lens used in this projector shown. Magnification of the mirror must be such as to image the evenly bright portion of the crater of the arc over an area slightly larger than the rectangle of the film gate. In this way, some light is spilled around the rectangular opening of the gate.

It will be noticed on the upper portion of Fig. 2 that the speed of the mirror is about the same as the speed of the lens. In fact, if the lens is any faster than the mirror, it will not increase the illumination on the center of the field, although the mirror being faster will help the illumination on the edge of the field in the case of the shorter focal length lenses.

The tube opening in the projector is usually made of such a size and shape that the lens can be made only of certain form and a certain diameter, and in most cases cannot pick up all of the light from the mirror. This normal mirror is actually much too small to function properly with shorter focal length lenses. It is, however, sufficiently large to function with some degree of success on longer focal length $f/2$ lenses around 6 in. in focal length. In this case, a great deal of the light from the edge of the film gate coming from the edges of the mirror can

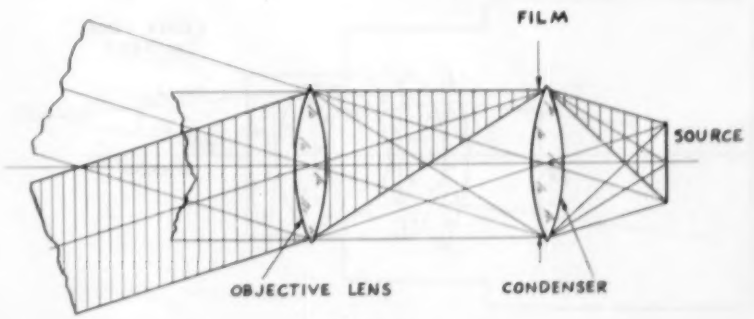


Figure 1.

Presented on April 22, 1955, at the Society's Convention at Chicago by John R. Miles, John R. Miles Co., 3724 Oakton St., Skokie, Ill. (This paper was received on March 31, 1955.)

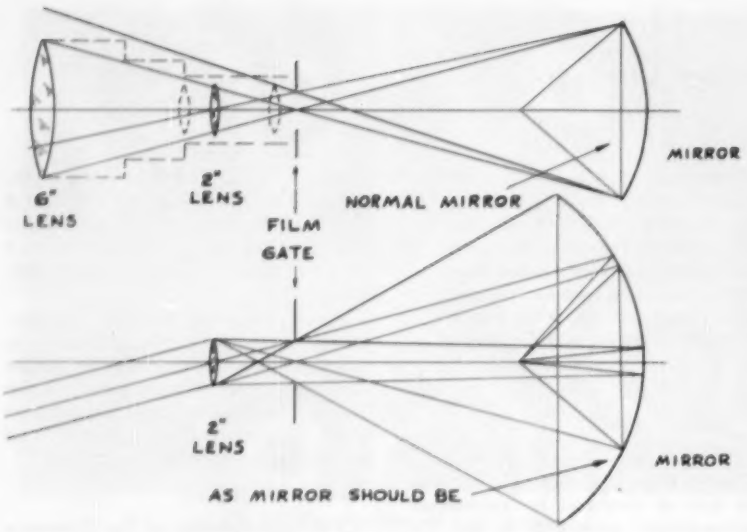


Figure 2.

go into the lens (actually about two-thirds). In the case of the 2-in. lens, as can be seen in the upper portion of Fig. 2, only half of this light can be picked up with an $f/2$ lens. In fact, neither lens could be made sufficiently large to pick up all this light coming from the edge of the mirror.

"Matched" Mirrors

It has been said by some writers that the mirror should be "matched" to the lens, that is, to have the same speed. This is, however, a misconception, and actually assures performance of the lens only for the center of the aperture plate. If the lens is to function properly, the mirror should be much larger to provide the light for the lens. In other words, the requirement is for the mirror to furnish light for the lens, and not for the lens to pick up the light coming from the mirror no matter where it goes.

The lower portion of Fig. 2 shows a properly designed mirror for functioning with a 2-in. $f/2$ lens. It will be noted that the speed of the mirror is approximately $f/1$.

It may not be practical to make mirrors of this diameter, but it is rather incorrect to blame the lens for fall-off in illumination when, actually, it is the mirror which is too small, particularly for short focal length lenses. It is sometimes stated that with the normal mirror the light from the mirror falls off onto the edge of the tube, and is lost. But actually, it is more correct to think of the fact that the light which goes above and below and to the right and left of the mirror out against the side of the lamphouse is lost, since this light, by simple optical principles, should be picked up by the mirror and directed towards the lens.

Stops for Optical Systems

All optical systems have a stop or aperture ring through which all the bundles of light from the center of the field, as well as all other parts of the field, must pass. The simple, inexpensive camera lens, for example, has this stop in front or behind the simple lens, and this means is used for correcting some of the aberrations.

However, good photographic lenses, such as the Cooke Triplet, the Sonnar, the Biotar, etc., have an internal stop, and this stop is used in their design when the aberrations are corrected through very elaborate computations. Practically, all projection lenses are adaptations of photographic objectives, and are designed with internal stops, and such stops are located inside the lenses (between the elements). With a normal mirror, as shown in the upper portion of Fig. 2, an artificial condition is produced in which the stop of the optical system is placed back at the edge of the mirror, and then this edge of the mirror is imaged in front of the projection lens, usually about 2 in. in front, and the bundles of rays through the lens do not meet the requirements of the designer, and serious vignetting is produced by artificially locating the stop in this manner. This also increases the aberrations of the lens, and harms the image quality.

The large mirror shown in the lower part of Fig. 2 would allow the projection lens to function in the manner in which it was designed, and the vignetting would be cut to a minimum.

There are, however, difficulties which might be produced by the very large mirror shown in the lower portion of Fig. 2. One difficulty would be too much heat on the film, but this could be overcome by decreasing the current in the arc, and obtain even illumination rather than a bright spot in the center of the screen. Another difficulty is the excessive size of the lamphouse.

One method of overcoming excessive heat would be to use the new interference filter type of light deflector, in which case most of the heat could be thrown aside with only about a 10% loss of light. In this way, the light could be increased on the edge of the screen by as much as 20% or 30%.

Modern Projection Lenses

Figure 3 shows the Double Gauss type of projection lens which is used by some of the leading optical companies to obtain a fast lens up to $f/1.8$, or even $f/1.5$, in an attempt to compensate for the faulty design of the lamphouse. Usually, these lenses decrease the light in the center of the field by having eight air-glass surfaces, but they do increase the light on the edge of the field by their high relative aperture. These lenses are Anastigmats, that is, they are corrected for astigmatism, and have a relatively flat field. The back focal length in these lenses, however, is quite great, and consequently, the back lens of the system is placed at a considerable distance from the film gate so that this light coming from the edge of the mirror is spilled on to the tube of the projector. Actual measurements and calculations show that the 2-in. central beam is cut down to 1.3 in. for the edge of the field on this six-element Double Gauss, as shown on Fig. 3. An anastigmat lens of this speed with a strong rear lens of large diameter, and close to the film gate, would produce a better compromise and give

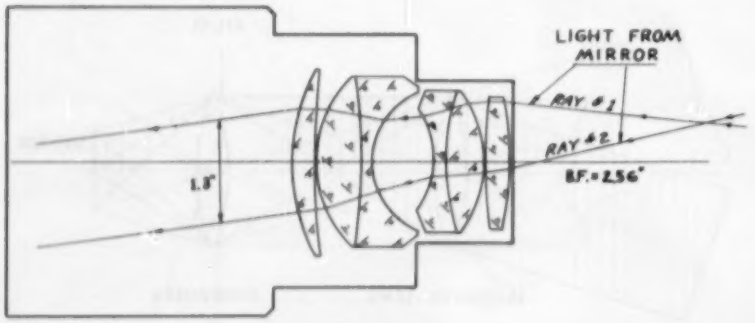


Figure 3.

more light, both in the center of the field and on the edge of the field. At one time, it was thought that the long back focus, or distance from the rear lens to the film, was an advantage, but, actually, this is not the case.

Petzval Lenses

Some of the older projection lenses which were made in the form devised by Petzval many years ago compensated for this defect in the lamphouse and mirror design to such an extent that the operators and theater owners tend to blame the newer short focus lenses for the fall-off in illumination. The way in which the Petzval lenses compensated is shown diagrammatically in the upper portion of Fig. 2. The two lenses shown in dotted lines indicate the front and rear elements of the Petzval lens, which, combined, produce a 2-in. focal length lens. It will be noted that the strongly spread ray coming from the edge of the mirror, and passing through the edge of the film gate diagonal, is intercepted by this lens, and, thereby, directed toward the front element and thence out to the screen.

The fortunate coincidence of this compensation probably has been one cause for delay in overcoming the defect in the lamphouse design.

From the practical side, it is probably better to attempt to overcome this defect in the lamphouse by a new style of lens than to try to persuade all of the theater owners, as well as the lamphouse manufacturers, that they should have a new lamphouse design. In fact, realistically, this is about all that can be done at this time.

New Type of Projection Lens

In order to accomplish this result, Projection Optics Company of Rochester, N.Y., is now producing a line of projection lenses, called the Super Hilux line. These lenses have a strong rear element close to the film gate, and thus have a greater light collecting ability, or, as we call it, a greater "light collecting speed." The term "light collecting speed" is defined by the expression:

$$\text{Back Focal Length} \div \text{Effective Diameter of Rear Element}$$

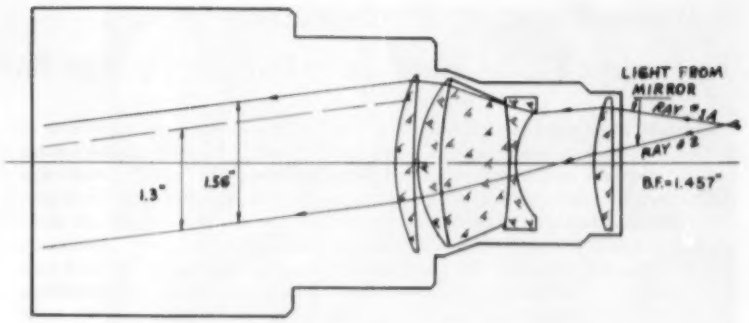


Figure 4.

The diameter of the rear element in the new Super Hilux is substantially equal to its distance from the film gate, and thus the lens is said to have an $f/1$ light collecting speed, which is not to be confused with the normal "focal length speed" of the lens. This lens is shown in Fig. 4, and it can be seen from this illustration that the construction differs considerably from the older type Double Gauss, which was shown in Fig. 3.

One advantage of the new lens is that there are only six air-glass surfaces, and these are practically all curved away from the film gate. This fewer number of air-glass surfaces increases the light transmission by several percent, and increases the contrast as well. The curvature of all air-glass surfaces, away from the film gate, also helps to increase the light transmission and contrast. This new lens is a true anastigmat, and basically of the Gauss design, although the central component is made thicker to gain from the aberration standpoint. The thick central crown element is made of high transmission glass of relatively low index, but is cemented between two glasses, which are particularly chosen to function well with low reflecting film, so as to further increase the transmission of the lens.

In September 1950 Dr. Willy Merté stated in his treatise and index on Zeiss formulae that this style lens used in the Super Hilux is probably the best type of lens yet designed. (Doctor Merté was in charge of the Optical Design Dept. at the Zeiss Works until the surrender of Germany at the end of World War II.)

The field curvature of this lens is fully corrected, as is the spherical aberration, and the definition, as well as contrast, are excellent.

The rays of light from the mirror have been determined by measurement and calculation, and are shown on Fig. 4 to come out of the Super Hilux lens with a separation of 1.56 in. It will be noted that ray 2 of Fig. 4 is the same ray as ray 2 of Fig. 3. This ray comes from the upper edge of the mirror. Ray 1A on Fig. 4 is a higher ray than ray 1 on Fig. 3, because the rear element of the Super Hilux is larger and closer to the film gate than is the rear element of the Double Gauss. This ray 1A then exits from the lens in such a way as to make the edge bundle, 1.56 in., higher than the 1.3 in. of the Double Gauss. This shows clearly that the Super Hilux has a larger edge bundle of light, and thus greater illumination on the edge of the screen.

Conclusion

In conclusion, the lamphouses and mirrors could stand some further improvement, but in the meantime lenses which compensate for the spreading of the light on the tubes of the projectors are helping to solve the problem of more illumination on the screen, and, particularly, on the edge of the screen.

A 16mm Projector for Operation With a Television Film-Chain on a Partial-Storage Basis

By EDWIN C. FRITTS

This paper describes the modification of a 16mm television projector — now in service with the iconoscope tube on a full-storage basis — for use with the vidicon camera tube on a partial-storage basis. This makes available, for the reproduction of film in a television system, the advantages of the vidicon tube for black-and-white film and makes it possible to project color film into a three-vidicon chain when it becomes available. The requirements associated with flicker are detailed, and the sequence of events that is necessary for partial storage is compared with that required for full storage. It is shown that a 2–3 system separates the pulldown by the required integral number of television fields and yet maintains the usual 2½ to 1 ratio between television fields and motion-picture frames. Further account is taken of the phasing necessary between the pulldown motor and the shutter motor, and the changes required in the design of the shutter. Under the heading of mechanical details, there is a description of the accelerator that provides the 2–3 sequence, and a discussion of the features provided to ameliorate the conditions introduced by more complicated accelerations and greater noise. In conclusion, the paper cites the results of a durability test and reviews the features of the installation and maintenance of the 2–3 system.

THIS PAPER pertains to a modification of the Eastman 16mm Television Projector Model 250 previously described in the *Journal*.[1,2]

With the development of a vidicon camera tube having superior storage characteristics, it is now possible to obtain much better results in projecting motion pictures into a television film-chain than is possible with the iconoscope. The latter operates on a full-storage basis, which restricts the exposure time to the extremely short blanking interval between television fields. The vidicon also affords one means of projecting color films into television. Neuhauser and Kozanowski have described its use for film reproduction.[3,4] This type of operation requires the extension of the exposure into the field itself, while actual scanning is taking place. To distinguish this from full storage with the iconoscope, it is called partial storage here. If the exposure extends over 30% or more of the scanning interval, no difference is observed on receiving screens between the areas that are lighted when they are scanned and those that are dark. However, the flicker caused by differences in the illumination pattern between fields is much more critical. For this reason, it is necessary to have the pattern of dark-scanned and light-scanned areas the same in each field.

The term "shutter bar" has arisen in full-storage operation and describes the bright bar that shows in the center of the screen when the shutter motor is 180° out of phase. This bar must be confined to the vertical retrace interval when no scanning takes place. The frequency of the power supply to the shutter must be exactly that of field frequency.

In the very nature of partial-storage operation, there is no visible "shutter bar" and this exact match of frequency between the shutter and the field frequency is not necessary. This is of prime importance in color work when the field frequency is slightly less than the 60 cycles of commercial power.

The 2-3 Modification of the Model 250

After reviewing the pulldown sequence of the Model 250 projector operated with full storage, the following description indicates the modifications necessary for partial storage.

With a full-storage iconoscope, the exposure takes place during vertical blanking, and thus the total scanning time is available for the pulldown action. This imposes no requirement that the pulldown occupy a particular portion of a field. The pulldown action of the regular Model 250 projector occupies somewhat less than half a field, and it takes place at intervals of 2½ fields. Thus, it occurs alternately in the first and second halves of the fields. If the polarity of the rotor of the motor is reversed, the pattern of the pulldown action shifts by half a field. However, in either polarity, the action clears the open interval of the shutter, so that no phasing is necessary. This is illustrated in Fig. 1, where the four boxes marked A represent the pulldown intervals. The shutter is open during vertical blanking, as shown by the narrow white sectors.

The problem of adapting this projector to the 2–3 pulldown action for partial-storage is three-fold.

First, all the pulldown actuations must occur in the same portion of the fields in which they fall. This means that they must now be separated by an integral number of fields. If this is made an alternate separation of two and three fields, the average will still be 2½ fields, as required by the 24-frame frequency of motion pictures and the 60-field frequency of television. All the pulldown movements will occur in the same — for example, first — half of the fields, and all the intervals when the shutter may be open will be in the last half of the fields. Again refer to Fig. 1. The boxes marked B show the new pulldown sequence. Again the shutter-open intervals, now occupying the second half of each field, are shown in white. Thus, with the shutter open during the same portion of each field, the requirement for the reduction of flicker is fulfilled. This is possible because in the fields where they occur, the pulldown actuations are all placed in the shutter-closed halves of the fields. This pattern has come to be known as the 2–3 pulldown system. An off-center type of accelerator described later is the means of so locating the positions of the pulldown movements.

The second part of the problem involves the phasing of two of the motors in the projector. Since the motor driving the shutter is mechanically isolated from that driving the pulldown, and since the shutter is now to be open for approximately half a field, the polarity of these motors must be such that the pulldown always occurs in the half-field in which the shutter is closed. This phasing becomes exclusively a mutual adjustment of the motors and has no specific relationship to the scanning sequence. Accordingly, in the phasing section, the shutter motor receives its intelligence, not from a half-wave of the 60-cycle voltage as previously, but from a commutator-and-brush assembly on the vertical motor similar to that used on the shutter motor. With this arrangement, the motors are phased mutually, but the pulldown may occur in the first or second half of the

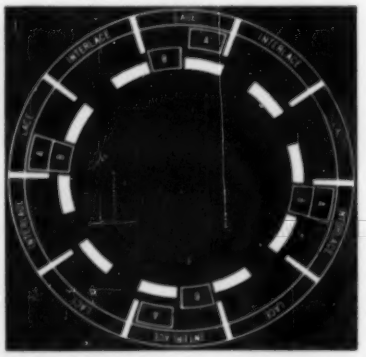


Fig. 1. Timing of the projector functions with respect to television fields. Blocks A apply to full-storage operation, while Blocks B are for partial storage.

Presented on October 19, 1954, at the Society's Convention at Los Angeles by T. Gentry Veal for the author, Edwin C. Fritts, Camera Works, Eastman Kodak Co., 333 State St., Rochester, N.Y.
(This paper was received on June 30, 1955.)

field, depending on the polarity of phasing of the motors, each time they start, with respect to the scanning cycle. However, this phasing remains the same throughout a given run. If it should be necessary, for some currently unforeseen reason, to maintain an identical pattern in successive runs—or a specific relationship with respect to the blanking interval—each motor could be phased independently with respect to the half-wave of the 60-cycle voltage, as in the Model 250. In the interest of simplicity, this feature has not been incorporated in the present model.

The third aspect of the problem is that the shutter of the standard Model 250 projector must be altered so that it provides the half-field exposure. Since alteration of the old shutter in installed equipment would require a balancing operation, the present plan is to furnish a new shutter disk rather than attempt to have the old shutter altered in the field.

Mechanical Details

Figure 2 shows the conversion mechanism attached to the projector, but with the enclosing case removed. The casting A carries a quill B. This quill is a cylindrical housing containing two shafts. The input shaft is driven at 720 rpm by motor C through timing belt D. It is displaced from the axis of the quill, while the output shaft is on the axis of the quill and has a spline driven by an "eye" on the input shaft. This combination forms an accelerator similar to the pair used in the intermittent system of the standard Model 250 projector, as described in the previous papers. The eye is located at a radius of 0.562 in., while the displacement of the shafts is 0.174 in. With this geometry, alternate rotations of $\frac{2}{3}$ and $\frac{3}{3}$ of a turn of the input shaft result in half-turns of the output shaft. When the action is transmitted to the intermittent mechanism through timing belt E at a 2 to 1 ratio, the result is one complete revolution of the pulldown — one motion-picture frame — alternately for $\frac{2}{3}$ and $\frac{3}{3}$ of a revolution of the input shaft. Since a television field is equivalent to $\frac{1}{3}$ of a revolution of this input shaft, the pulldown actuations are thus spaced alternately two and three fields apart.

The 2–3 pattern increases the complexity of the accelerations of the pulldown mechanism and precludes the use of the flexible coupling — present in the Model 250 projector — that ordinarily minimizes these disturbances. Accordingly, the forces reflected back into the motor are greater in the 2–3 model, and more clearance is needed in the synchrogears. For that reason, the stack of gear elements is increased from two to three, and instead of alternate teeth, two are omitted from successive groups of three teeth.

Furthermore, these more complex accelerations generate more noise in the drive. This is reduced by provision of shock-mounts between the main casting and the accessory casting A, Fig. 2. Despite the more severe conditions, running tests of the mechanism conducted over the period of more than 1,000 hr fail to show indications of wear. In these tests particular attention was paid to the timing belts since they are relatively new in our experience. Furthermore, the accelerations imposed on them present unique conditions of loading.

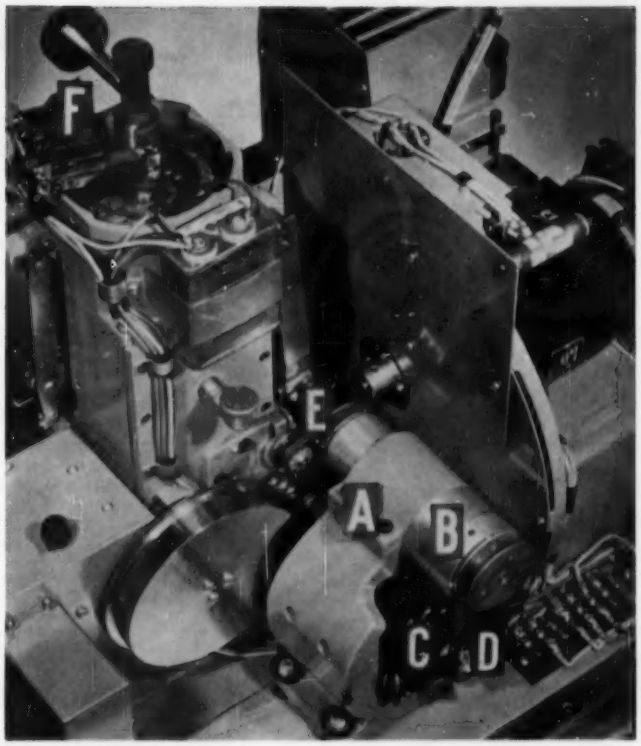


Fig. 2. Details of the new drive that provides the 2-3 operation of the pulldown assembly.

Installation and Maintenance

The motor and quill are mounted in one casting that replaces the 1440-rpm motor and its supporting casting. Similarly, the shutter disk can readily be replaced, and the phasing magnet F, Fig. 2, is attached to the vertical motor with simple tools. Fortunately, there is room for such a magnet in the enclosing case for the Model 250 projector. Moreover, the phasing of the accelerator to the intermittent is not a difficult operation.

Finally, the lubrication of the system is designed for infrequent attention. Both the motor shaft and the output shaft of the quill run in ball bearings that are lubricated for life, while the input shaft of the quill runs in a bronze bearing. The latter and the pin and spline are lubricated by a film of oil maintained by a supply of oil stored in a pad of felt. This should not need attention more frequently than once in several months.

Conclusion

This paper describes a means of adapting the Eastman 16mm Television Projector Model 250 for operation on a partial-storage basis. By this change, the Model 250, which has already established itself in the television field, can be used for the projection of color film into a three-vidicon chain.

Any of the Model 250 projectors now in use can be altered as described above without interference with scheduled programs. A projector so modified can still be used with the iconoscope if the old shutter is retained. However, with the new shutter, the advantages inherent in projection of black-and-white film into a single vidicon become available, and the projector is ready for use with the three-vidicon color chain.

References

1. Edwin C. Fritts, "Heavy duty 16mm sound projector," *Jour. SMPTE*, **55**: 425–438, Oct. 1950.
2. Edwin C. Fritts, "16mm projector for full-storage operation with an iconoscope television camera," *Jour. SMPTE*, **61**: 45–51, July 1953.
3. R. G. Neuhauser, "Vidicon for film pickup," *Jour. SMPTE*, **62**: 142–152, Feb. 1954.
4. Henry N. Kozanowski, "Vidicon film-reproduction cameras," *Jour. SMPTE*, **62**: 153–162, Feb. 1954.

motion-picture standards

American Standard—PH22.98-1955

Published on this page is American Standard PH22.98-1955, 35mm 3-Track Magnetic Flutter Test Film, approved by the American Standards Association on July 8, 1955.

This standard had its trial publication in the February 1954 *Journal*. A phrase, "at any rate," was omitted by error from section 2.6 of the standard and a correction to this effect was published in the February 1955 *Journal*. In the subsequent processing of the standard quite a few modifications were adopted which improved the wording and made for greater clarity but left the substance unchanged. This standard thus differs in several ways from the draft published initially.—*Henry Kogel*, Staff Engineer

American Standard

35mm 3-Track Magnetic Flutter Test Film

ASA
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PH22.98-1955
*UDC 778.534.4

1. Scope

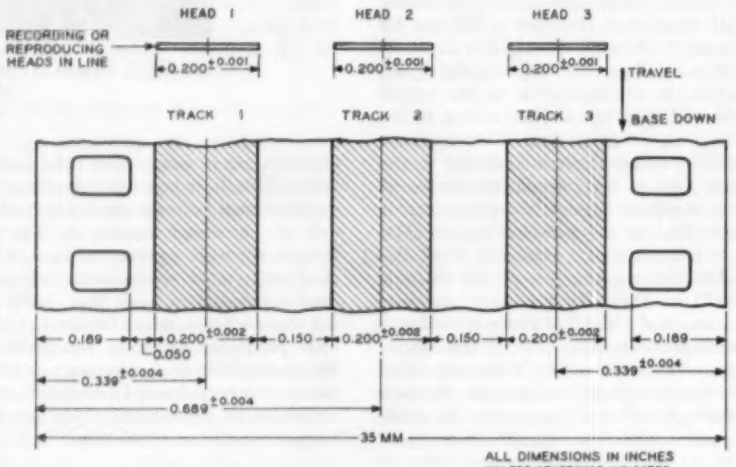
1.1 This standard specifies a 3000-cycle magnetic sound test film for use in determining the presence of flutter in 35mm magnetic sound reproducers.

2. Test Film

2.1 The test film shall have an original magnetic sound recording.

2.2 The coated side and direction of travel shall be as specified in American Standard PH22.86-1953, 200-Mil Magnetic Sound Tracks on 35mm and 17½mm Motion-Picture Film, or the latest revision thereof approved by the American Standards Association, Incorporated, and the base shall be coated from one row of perforations to the other row, or from edge to edge.

2.3 Three sound records shall be recorded in accordance with the dimensions specified in American Standard PH22.86-1953 (as shown in the drawing below) or the latest revision thereof approved by the American Standards Association, Incorporated.



ALL DIMENSIONS IN INCHES UNLESS OTHERWISE INDICATED

2.4 The recording frequency shall be 3000 ± 25 cycles per sec with a film travel rate of 96 perforations per sec (approximately 90 ft per min).

2.5 The modulation of the recording shall be such that the total harmonic distortion does not exceed 2½%.

2.6 The total rms flutter of the sound recorder shall not exceed 0.1% and the flutter amplitude at any single flutter rate shall not exceed 0.05% (as defined in American Standard Method for Determining Flutter Content of Sound Recorders and Reproducers, Z57.1-1954, or the latest revision thereof approved by the American Standards Association, Incorporated).

3. Film Stock

3.1 The film stock used shall be of the low-shrinkage, safety type, cut and perforated in accordance with American Standard PH22.36-1954 Dimensions for 35mm Motion Picture Positive Raw Stock, or the latest revision thereof approved by the American Standards Association, Incorporated.

4. Film Length

4.1 The film shall be supplied in 50-ft lengths or multiples thereof.

5. Identification

5.1 Each test film shall have suitable identification markings.

Approved July 8, 1955, by the American Standards Association, Incorporated
Sponsor: Society of Motion Picture and Television Engineers
*Universal Decimal Classification

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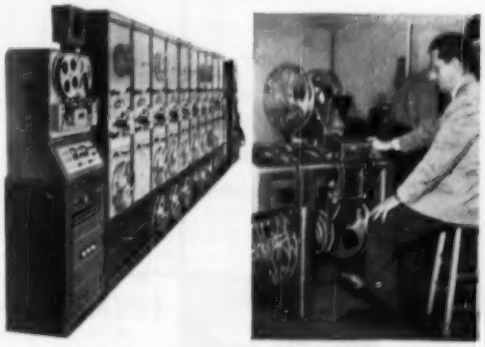
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AT LEFT: Lineup of dubbing machines and dubbing recorder. Re-recorded version is 6-track stereophonic sound on 35mm magnetic film. AT RIGHT: Westrex Editer—with 70mm film in the picture gate, and two 35mm sound films, one in the regular gate and one in the special sound head attachment.

news and reports

SMPTE Education Committee

The first concrete results of the program undertaken by the Society's Committee on Education have been achieved with the initiation in mid-September in Los Angeles of three courses of instruction for film industry technicians. These courses are sponsored by the Society in cooperation with the University of California, and are meeting once a week for eighteen weeks at the John Burroughs Junior High School, 600 South McCadden Place, Los Angeles.

A course in "Motion-Picture Laboratory Practice" will be held Thursday evenings and will be conducted by six experts in the field. They include: Dr. John G. Frayne of Westrex Corp., President of the Society and Chairman of the Society's Education Committee; William Gephart, Processing Director of General Film Laboratories; Alan Gundelfinger, Plant Administration, Technicolor Motion Picture Corp.; Allen Haines, Chief Chemist, Pathe Laboratories, Inc.; Donald H. Kelly, Member of the Research Staff, Technicolor; and Sidney P. Solow, Vice-President and General Manager, Consolidated Film Industries.

This course will include sessions on sensitometry, photographic chemistry, laboratory aspects of sound, practical laboratory practice and color. Prerequisites for enrollment is experience in motion-picture laboratory work.

On Monday evenings a course in "Illumination Optics" will be conducted by Ernest W. Silvertooth, Engineer, Librascope, Inc. This course will cover general image-forming optics; optics in illumination systems, light sources, optical glass characteristics, optical quality of film images and optical filters. College physics and consent of the instructor are necessary for admittance.

Roderick T. Ryan, Quality Control Engineer, Eastman Kodak Co., will conduct a course on "Duplication of Color Motion Pictures" on Wednesday evenings. Experience in printing and/or processing of color motion-picture film and consent of the instructor are necessary prerequisites for taking Mr. Ryan's course.

These three courses are the direct result of the activities of the Education Committee's Subcommittee on Training of Film Laboratory Technicians of which Mr. Solow is Chairman. This was one of five subcommittees appointed by Dr. Frayne following the first meeting of the group held in Hollywood on April 5, 1955. At that meeting the Chairman discussed the need for supplying trained engineers and technicians for the industry as well as the need for continued training on the job of those employed in the industry. It was then decided that the future work of the committee should be built around the following items:

(1) Making an inventory of jobs that might be available for the next ten years. A part of this study would aim to establish a roster of technical employees in the industry.

(2) Establishing short courses or institutes to meet current problems in the industry.

(3) Establishing a long-range training program.

The five subcommittees established to implement the various parts of this program include, in addition to the Subcommittee on Training of Film Laboratory Technicians: Studio Joint Subcommittee on Education Training, headed by Loren L. Ryder of Paramount; Film Laboratory Joint Subcommittee on Educational Training, headed by Alan Jackson of the Film Technicians Local; Subcommittee on Training of Sound Technicians, headed by Lorin D. Grignon of Twentieth Century-Fox; and a Subcommittee on the Training of Television Technicians, headed by Herbert W. Pangborn of CBS.

The Committee on Education is made up of representatives of universities, labor unions, motion-picture and television studios and laboratories who are anxious to cooperate to meet the growing need for trained technical people in the industry. Those on the Committee include:

Herbert Aller, Business Rep., Local 659, IATSE, Los Angeles

Charles Austin, Technical Rep., Mitchell Camera Corp., New York

Chester Bahn, Editor, *Film Daily*, New York

Wilbur T. Blume, USC

L. M. K. Boelter, Dean of Engineering, UCLA

Thomas A. Carman, International Sound Technicians Union, Hollywood

John W. Ditamore, Manager, Hall of Music, Purdue University

John Flory, Advisor on Nontheatrical Films, Eastman Kodak Co.

Lloyd T. Goldsmith, Sound Department, Warner Brothers Pictures, Inc.

E. E. Griffith, Research Engineer, Technicolor Motion Picture Corp.

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John K. Hilliard, Chief Engineer, Altec Lansing Corp., Los Angeles
Alan Jackson, Film Technicians Local 683, Hollywood
P. A. Jacobsen, University of Washington, Seattle
Wm. F. Kelley, Sec.-Treas., Motion Picture Research Council, Hollywood
Ellis F. King, UCLA
Ralph E. Lovell, Kinescope Recording Supervisor, NBC, Hollywood
John Mahon, Producer, Newport Films
Arthur C. Miller, President, ASC, Hollywood
Garland C. Misener, Ansco, Binghamton
Hollis Moyse, Photographic Products Dept., E. I. du Pont de Nemours & Co., Hollywood
H. W. Pangborn, TV Engineer, CBS, Hollywood
Loren L. Ryder, Director of Engineering & Recording, Paramount Pictures Corp.
N. L. Simmons, Motion Picture Engineer, Eastman Kodak Co., Hollywood
Sidney P. Solow, General Manager, Consolidated Film Industries
Henry Ushijima, Director of Production Services, Geo. W. Colburn Laboratory, Chicago
Robert Wagner, Ohio State University, Columbus

Commercial TV in Britain

Britain's first independent commercial television station began transmitting on September 22 from Croydon, near London, where equipment provided by Marconi has been installed and put into operation. The station has, in fact, been hand-built and the 10-kw vision transmitter and the 2½-kw sound transmitter are both "laboratory prototypes." Two more transmitters of approximately the same power outputs will be installed in the near future. These will be standard production versions. The three transmitters together will reach almost 60% of the English population. Stations will continue to be opened at the rate of one a year, until the total of 14 or 15 needed gives complete coverage.

The new station is owned and operated by the Independent Television Authority, or ITA, set up in August 1954 by Parliament, with a statutory life of 10 years. Programs are produced by private companies called "program contractors." These companies must get ITA's approval regarding taste and subject matter, in order to maintain a balance in the types of programs presented.

A private specialist organization, the Independent Television News Ltd., will produce all news shows and supply them to the private companies. ITA will pass on the accuracy and impartiality of the news.

To finance ITA, the Government is lending the organization up to £2,000,000 ($5,600,000) within the next five years, with arrangements made for additional, special government grants if necessary. The bulk of its finances, however, will come from selling time on its stations to private production companies.

The companies that produce the programs will sell advertising time within the shows but advertisers will not be permitted to "sponsor" shows. ITA controls the amount of time allotted to advertising and prescribes that commercials can come only at the beginning or end of programs, or in natural breaks in the script or program. There must not be more than six periods of advertising in an hour and none in programs of religion, royalty or national ceremonies.

BBC will continue its present program and may begin a second channel when allotted a wavelength but it will not become a commercial television service.

The Director-General of ITA, Sir Robert Fraser, has stated that there are likely to be 40 or 50 stations when commercial television is fully developed, all operating independently of each other.

10-kw Transmitter

The production version of the Marconi Band III 7½/10-kw vision transmitter will consist of a 2-kw transmitter together with a Band III Amplifier. The transmitter is housed in four standard cubicles, and the amplifier in three, all of which may be bolted together to form a continuous front.

The complete transmitter is designed to give a peak output power of approximately 10 kw under vestigial sideband conditions, at any chosen channel in the upper frequency band of 170 to 216 mc, using the British standard 405-line system. Other editions give similar facilities on 525- and 625-line systems.

Air cooling is used throughout for normal operation, and the transmitter incorporates the most advanced constructional techniques, the general design being based on the policy of generously under-running all components and valves so as to secure long life and high reliability. All units are readily accessible for maintenance.

Pushbuttons are provided on a Transmitter Control Panel for normal day-to-operation of the transmitter, which may thus be brought up on power from the control desk. The voltage and feed of the final amplifier are metered; a black level control and calibrated input attenuator are also provided on the control panel.

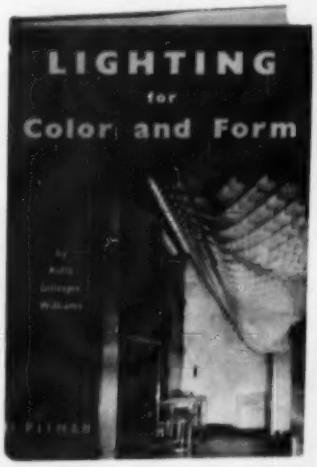
2-kw Transmitter

Drive Circuits: Crystal controlled. The crystal itself is oven-controlled and operates at a submultiple of the output frequency. Long-term stability better than 0.0002%, which permits offset carrier operation of two adjacent transmitters on the same channel. The crystal oscillator, together with associated frequency multipliers and stabilized HT supply, form a complete unit with an output of approximately 15 w at the operational frequency.

RF Circuits: The first and second RF amplifiers consist of triode valves working in single-ended grounded grid circuits, using coaxial lines as circuit elements. The final (modulated) amplifier employs an air cooled tetrode in a single-ended coaxial line circuit.

Modulator: The output signal from the control desk is bridged across the input of

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two units, namely a clamp pulse generator and a correction unit.

Clamp Pulse Generator: This produces a clamping pulse of 2-v amplitude, which will remain correctly timed in presence of noise pulses on the incoming signal, positive or negative, up to 1½-μsec duration.

Correction Unit: In this unit the sync pulses are stretched, clipped to standard level, and pre-correction applied to compensate for transmitter nonlinearity. A fine gain control is provided on this unit. Signals are clamped by pulses from the clamp pulse generator, and the output is approximately 1.5 v double amplitude peak to the next stage, the preamplifier.

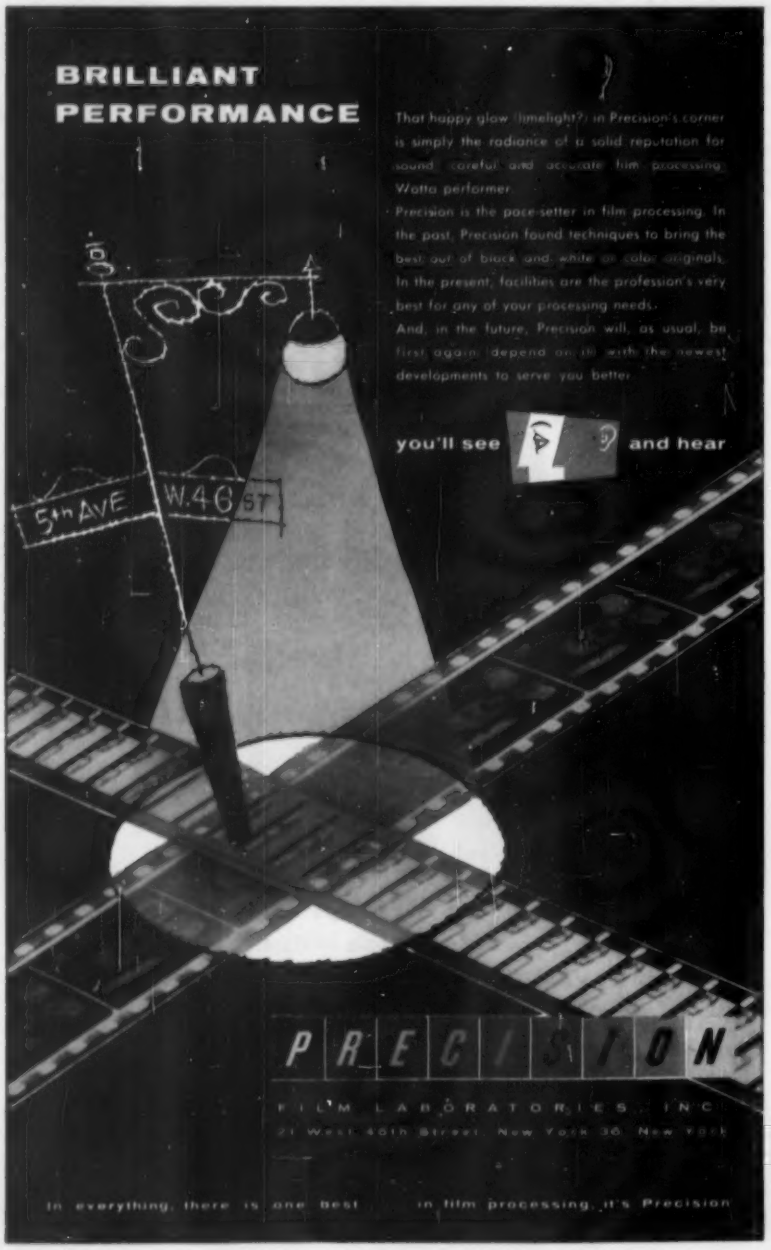
Preamplifier: Here the signal can be increased to approximately 50-v DAP. Since the input is correctly clamped, the black level is maintained in the succeeding stages by d-c restoration. Coarse, and fine preset gain controls are provided on this unit.

Final clamping and Black-Level Feedback Unit: A signal is obtained via a probe in the aerial feeder rectified, and fed to this unit. The amplitude of the sync pulse in the signal thus derived is used to maintain the black level constant. The signals are also clamped by pulses from the clamp pulse generator. Should a fault occur in the feedback path, the feedback control may be switched out of operation.

Final Amplifier and Modulator: The unit is fed from the final clamping stage through an input cathode follower, the whole circuit being directly coupled to maintain the constancy of black level. A cathode follower feeds a normal shunt regulated amplifier, followed by a shunt regulated cathode follower stage, in order to supply the large reactive current demanded by the stray capacitance appearing at the modulation terminals of the amplifier. A peak modulation limiter is incorporated in this unit.

Band III Amplifier

The modulated output of the 2-kw transmitter is fed to the input of this amplifier, which consists of a single-ended air-cooled triode operating in a coaxial line circuit to raise the output level to approximately 10 kw peak.



Wide-Screen Motion Pictures

The Society has just produced a brief booklet on wide-screen motion pictures. It is a comprehensive outline of the several new methods of motion-picture production and exhibition that came into use during and after 1952, and an indication of the ways in which they differ from the techniques that became "standard" during the late nineteen twenties.

The booklet, which was prepared at the suggestion of Ralph Hetzel, Vice-President of the Motion Picture Export Association, covers 35mm sound pictures, Cinerama, CinemaScope, VistaVision, Superscope and Todd-AO. Details of camera aperture, projecture aperture, aspect ratio, direction and rate of film travel, number and type of soundtracks and loudspeakers, and type of screen are included in each section.

Copies are available at no charge to Society members upon request until present supply is exhausted—*S.G.*

Education, Industry News

The National Association of Educational Broadcasters has made a survey of the television in the U.S. and reports much activity in this field. During the past summer TV workshops were offered with an increasing emphasis on the technical side of the medium.

In addition to the writing, directing and program planning courses which are given by a great many institutions, the University of Miami, Coral Gables, Fla., offered a series of courses including: Studio Operations, Control Room Operations, Performance Skills, Set Construction and Graphics. Michigan State University at East Lansing, Mich., offered workshops in Production Methods, and Production Laboratory; and the University of Southern California, which recently installed a good deal of modern, up-to-date projection equipment, offered a comprehensive course in Control Room Operation, Television Laboratory and Telecommunications Workshop.

Membership Certificates (Active and Associate members only). Attractive hand-engrossed certificates, suitable for framing for display in offices or homes, may be obtained by writing to Society headquarters, at 55 West 42d St., New York 36, Price: $2.50.



Meet Los Angeles "SCOTCH" Brand Account Executive Tom Gibbons, Jr., wife Cleyo Sue and their five children—Tommy, Jacky, Susan, Maureen and Jeffry. A high fidelity music fan, Tom also finds time to take his young sons on week-end trips to the High Sierras.

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DECEMBER, 1948—a standout date for Tom Gibbons, Jr., motion picture industry Account Executive and member of the S.M.P.T.E. Just seven years ago he played an important role in helping the motion picture industry to adopt an entirely new sound recording method, now used by all major film companies for their original recordings. It's "SCOTCH" Brand Magnetic Film No. 115.

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James L. Wassell, Chairman of the Society's Central Section, was recently appointed Coordinator of a new department called the Professional Equipment and Instrument Division set up by Bell & Howell in Skokie, Ill., according to an announcement by George L. Oakley, manager of the division.

Wassell formerly was with Ansco where since 1949 he was midwest sales manager of the company's professional motion-picture division.

The new division at Bell & Howell is a further extension of the company's policy of developing and coordinating its efforts in designing new, specialized equipment for the professional and engineering fields. The number of sales and engineering personnel in this work has been quadrupled. This activity was formerly divided among the Bell & Howell engineering, manufacturing and merchandising divisions.

A special group will work on projects not suitable for the production line, and the division will concentrate heavily on research in the electronics field. Increased effort will be given to film printers and other equipment that the company pioneered for the motion-picture industry. Special research will be aimed at developing equipment to help film laboratories "automate" their operations.

Two other appointments have recently been announced, these by Malcolm G. Townsley, Vice President of Engineering: **John G. Heiland,** who was formerly Associate Director of research while Mr. Townsley was also serving as Director of Research, has been made Director of Research. **Gerhard Lessman,** formerly a special project engineer, has been made Associate Director of Research.

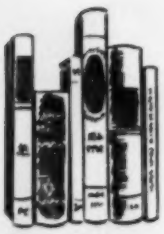
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books reviewed

How to Do Home Movie Tricks

By Julien Caunter. Published (1955) by Focal Press Ltd., London; available in U.S. from American Photographic Book Publishing Co., 33 W. 60 St., New York 23. 176 pp. 5 × 7¼ in. Price $1.75.

This compact little book brings a wealth of ideas and information to the student and amateur cine filmer. The professional will not find anything in it that he does not already know since all the tricks suggested are very simple in themselves or based upon the most elementary principles. Simple language and clear linecuts combine to inspire the amateur to look upon his camera with new interest and respect. Although the trick work described is primarily designed to amuse the filmer and his audience, it will undoubtedly provoke serious thought among students. The more serious application of these methods will permit many a random motion-picture enthusiast to become a serious worker in the field. The judicious use of the trick filming methods coupled with imagination and good taste will increase the value of films that would otherwise be very ordinary.

The chapter on varying camera speeds gives an unusually clear statement of the facts. Stop motion and animation come in for a very condensed but nonetheless informative pair of chapters which are well worth reading. Masks and before the lens effects are described in detail. All through the book there are very helpful general hints which apply to all types of filming and camera handling. Parallax errors in titling are adequately covered. A short chapter on editing, although not strictly keeping to the subject, has some hints worth considering.

The book as a whole makes a valiant attempt to cover a vast area of photography in a small amount of space. It succeeds in this without getting the reader involved in overly technical discussions.

The chapters devoted to animation and spot motion bring out some interesting and useful facts, but because of space limitations only the high spots are touched upon.

The glossary must be used with care because of the disparity between British and American nomenclature in some cases.

The fact that this book is too elementary to be of any use to the profesional cinematographer does not lessen its value and importance to the student and amateur. It will find a welcome spot in the library of these last two, and is technically accurate, complete and full of useful information



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The Bell System wanted a color film that would help prevent accidental damage to buried and aerial telephone cables by dramatizing some of the common causes of such damage and their effect on vital communications. SOUND MASTERS of New York was selected to make the film.

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SOUND MASTERS selected the Arriflex 35 Model IIA with Synchronous Motor and Sound-Proof Blimp — and filmed all the sequences with this equipment within a period of five weeks. *Speechless By Mistake* has been completed and will soon be released by the local Bell Telephone Companies for public showings.

Says Mr. F. C. Wood, Jr. vice president in charge of production, "We acquired and used the Arriflex outfit because it was the lightest, most compact equipment we could find. It would have been next to impossible to have done the job so quickly and easily with any other camera. The Blimp was perfect both indoors and out.

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which is conveniently arranged.—*E. M. Pittaro*, Consultant, 137-65 70 Ave., Flushing 67, N.Y.

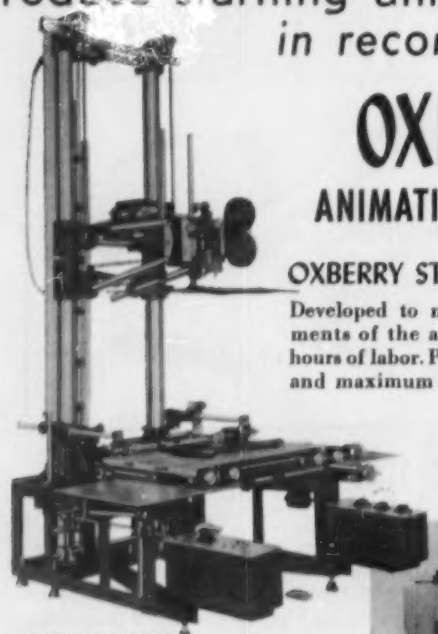
Leica Manual and Data Book

By Willard D. Morgan and Henry M. Lester. Published (1955) by Morgan & Lester, 101 Park Ave., New York 17. 456 pp. incl. illustrations, graphs and tables. 5½ × 8¼ in. Price $6.00.

Now in its thirteenth edition and twentieth year of publication, this perennial classic continues to hold its reputation as the outstanding work in its limited field. Its audience is the Leica camera owner, and to this audience it presents a detailed factual account of the camera and its proprietary equipment. The present edition has been extensively revised and rewritten. It includes exposure and filter data for such recent film stocks as Adox, Anscochrome and the new Ektachrome. Tables and formulas from many separate sources are now conveniently grouped together in a 57-page appendix. Previous conflicts in statements of flash exposure figures have apparently been resolved by the editors, and the tables which they now present are warranted to be reliable. The editors have performed well and faithfully their task of presenting an informative volume, undiluted by inspirational copy.—*Bernard D. Plakun*, General Precision Laboratory Inc., Pleasantville, N.Y.

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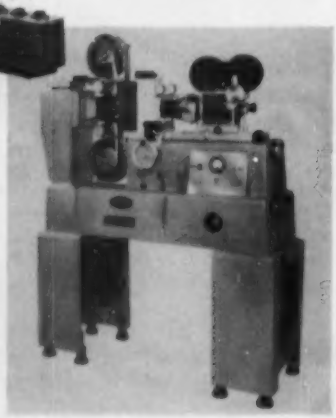
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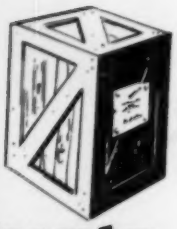
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Two six-channel stereophonic production recording systems were specially designed by Westrex Corp. for the Todd-AO production of *Oklahoma*. These systems consisted of mixer input facilities capable of accommodating six stereophonic microphone inputs, a six-channel RA-1547 Recorder and associated power supply equipment. Both were mounted in van-type mobile units containing their own power supplies.

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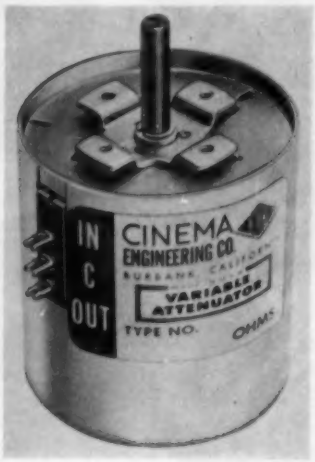
Plant: 847 King Street, Northampton, Massachusetts

New York Office: 30 Church Street, New York 7, New York

proper interconnection of all the circuits involved.

To reproduce the music, dialog and sound effects tracks associated with the re-recording operation, Westrex furnished twelve RA-1551 Type 6-Track Stereophonic Reproducing Machines and two RA-1547 6-Track Stereophonic Recording Machines. For monitoring the re-recording operation Westrex supplied five special horn systems for use behind the screen and two sets of surround speakers, with six special amplifier systems, each rated at 50 w. Associated with the dubbing monitor reproducing equipment are six special projection-type volume indicators and a projection-type footage counter.

The Westrex Editer was modified to accommodate two 35mm magnetic films each containing six stereophonic sound-tracks in association with the Todd-AO 70-mm picture film. The stereophonic sound conversions including the auxiliary six-track stereophonic reproducer were provided by Westrex.



A new manufacturers' type audio attenuator has gone into production at the Burbank, Calif., plant of Cinema Engineering Co., a division of Aerovox Corp. For use in sound mixing, special measuring and calibration units, the attenuator features Cinema self-wiping contacts of nickel, silver, carbon composition and wire-wound resistors. Available in 150, 250 and 600 ohms, the resistance element values are standard 5% accuracy. Audio ladder controls have a 6-db inherent insertion loss. All other network types of mixer controls have zero loss. Other rotary tap units are available in potentiometer, T, ladder attenuator networks. Controls are capable of handling levels as high as +30 dbm. The attenuator comes without knob and dial, but they are available as accessory items. Shipping weight is 8 to 12 oz per section.





Together with the latest developments in motion pictures and photography featured in Disneyland, Walt Disney's 160-acre park, the early days of photography have been revived in a gay-nineties, old-fashioned portrait studio and camera shop, created by Eastman Kodak on the "Main Street" entrance to the park. The professional photographer's studio is an exact replica of a studio of the nineties with a photographer and model posed with her head in the metal headrest typical of that period. All the cameras and equipment will be exact replicas of those used during that period. The historical exhibit shows the development of stereo photography, old-time "detective" cameras, and a Kinetascope, forerunner of the movies.

Eastman Kodak Company has obtained rights from Gasparcolor, Inc., to use the inventions of patents 2,344,084 and 2,312,543, according to an announcement by Dr. Bela Gaspar, President of Gasparcolor. These patents deal with the arrangement and color sensitivity of emulsion layers in a multilayer, multicolor photographic film.

According to patent 2,344,084 silver chloride emulsions insensitive to blue light (except for the short wave blue violet which is screened out) can be used for the two upper layers of a multicolor film and the lower layer can be an ordinary silver halide emulsion which is inherently blue sensitive. This permits the uppermost layer to be sensitized to green and the second layer to be sensitized to red so that the images which are subsequently converted to magenta and cyan, respectively, are recorded in the front of the film and consequently with greater sharpness. Thus the major role which these darker color images play in the overall definition of the final color print is more fully utilized. The arrangement also permits the elimination of a filter layer normally required to be used behind an ordinary blue sensitive silver halide layer when it is the uppermost layer of the film.

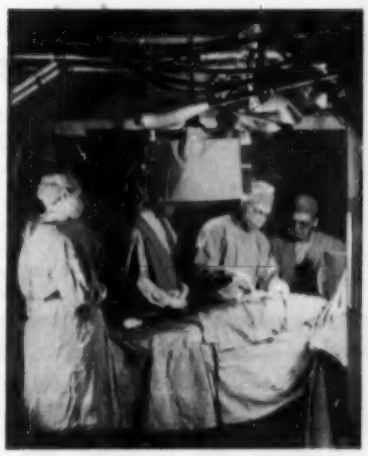
Patent 2,312,543 has to do also with the arrangement of color sensitive layers in which the relative speeds of overlying and underlying layers are utilized to obtain an advantage similar to that indicated above for the silver chloride emulsion patent.

Dr. Gaspar has announced that the rights granted are nonexclusive in character and that Gasparcolor, Inc., stands ready to license, on reasonable terms, other film manufacturers who may want to use the invention of either or both of these patents.

A new color television camera designed specifically for medical use has been developed by the Radio Corporation of America and first publicly demonstrated in Philadelphia at the Veterans Administration Hospital. The camera which is compact and flexible in design is mounted directly above the operating table. It picks up and transmits the scene to a mobile color TV unit outside the hospital and then by radio relay to a 15 × 20 ft theater-size television screen or to a standard 21-in. color set.

Speaking to the group in Philadelphia was Dr. Alfred N. Goldsmith, New York TV and electronics consultant. He envisioned a "Super Clinic" of hospitals throughout the country joined together by television conventions and pooling knowledge and techniques. Medical research and experiments can be carried on by using the compatible color camera with a light microscope, for color transmission of microscopic studies.

The new RCA color camera is compact and approximates the weight and size of standard black-and-white studio TV cameras. Reduction in size is achieved by using three vidicon pickup tubes similar to those used in industrial television systems. Light from the televised scene is divided into the three separate colors by a system of dichroic mirrors. Each vidicon tube has its own lens,



and the camera can be focussed remotely by a small reversible motor.

In addition to the vidicon camera the RCA compatible color system contains packaged units for camera control, monitoring, sync generation and regulated power supply. The system also includes a colorplexer and an r-f system to feed signals into standard home color receivers without alteration. The entire equipment weighs about 300 lb.

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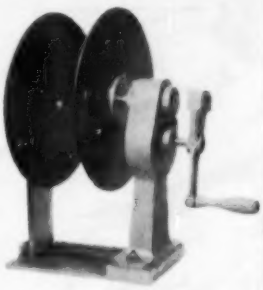
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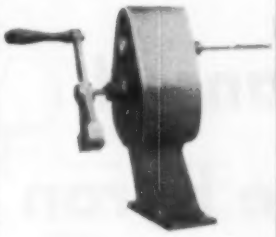
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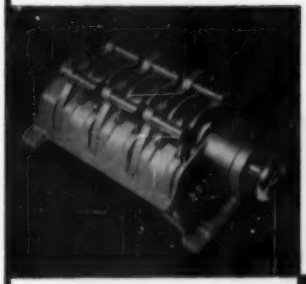
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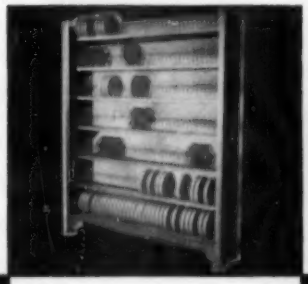
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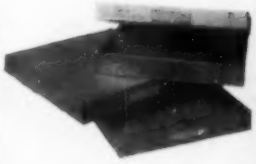


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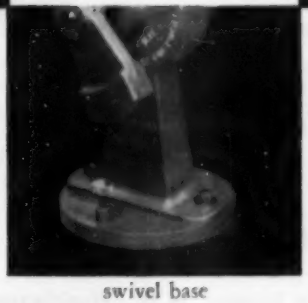


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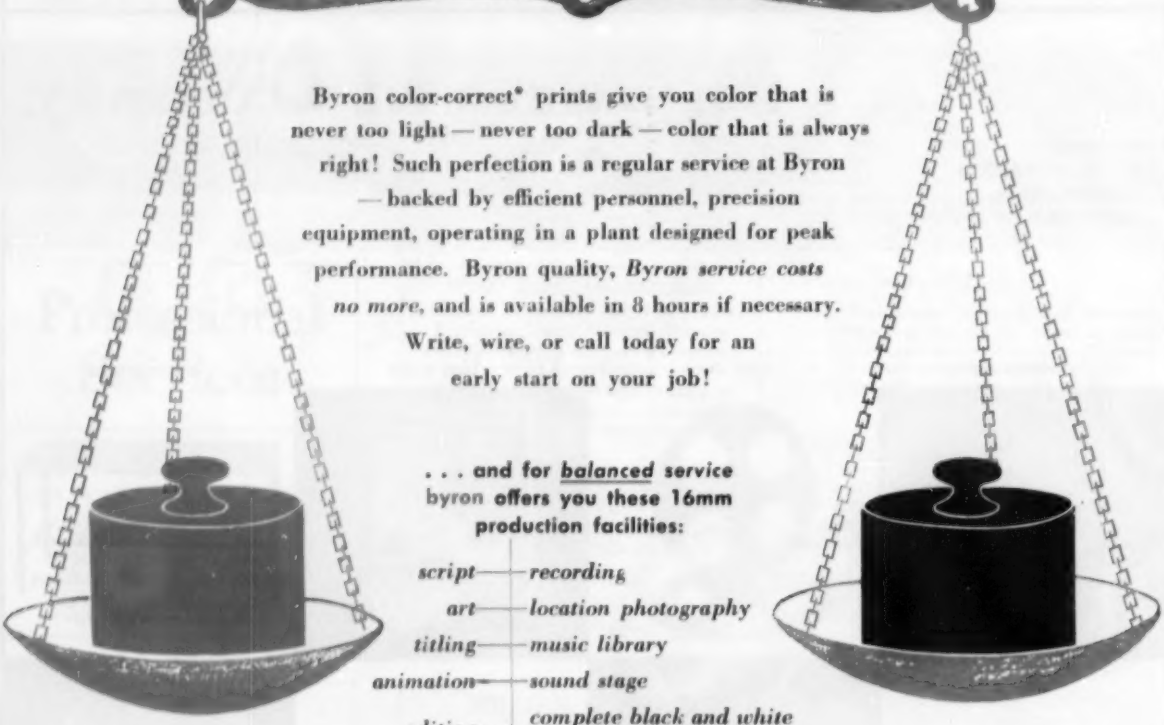


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American Standards Association, 37th Annual Meeting and Sixth Annual Conference on Standards, Oct. 24–26, Washington, D.C.

SMPTE Central Section, Oct. 28–29.

Aeronautical and Navigational Electronics, East Coast Conf., Oct. 31–Nov. 1, Lord Baltimore Hotel, Baltimore, Md.

Fifth Industrial Electric Exposition, Nov. 1–3, Hotel Wm. Penn, Pittsburgh.

National Academy of Sciences, Nov. 2–4, Calif. Institute of Technology, Pasadena, Calif.

National Electrical Contractors Association, Annual Convention, Nov. 2–5, Waldorf Astoria, New York.

Theatre Equipment and Supplies Manufacturing Association, Theatre Equipment Dealers Association, Annual Convention and Trade Show, Nov. 6–9, Morrison Hotel, Chicago.

American Rocket Society, Nov. 13–18, Chicago.

Communication by Scatter Techniques, Symposium, Nov. 14–15, sponsored by IRE and George Washington University, Washington, D.C.

Electrical Techniques in Medicine and Biology, Annual Conference sponsored by AIEE, IRE, and ISA, Nov. 14–16, Shoreham Hotel, Washington, D.C.

National Electrical Manufacturers Association, Annual Meeting, Nov. 14–18, Traymore Hotel, Atlantic City, N.J.

American Society of Mechanical Engineers, National Meeting, Nov. 13–18, Hotels Congress, Hilton and Blackstone, Chicago.

American Physical Society, Nov. 25–26, University of Chicago, Chicago, Ill.

American Institute of Chemical Engineers, Nov. 27–30, Hotel Statler, Detroit.

International Atomic Exposition, Dec. 10–16, American Institute of Physics, Public Auditorium, Cleveland, Ohio.

Acoustical Society of America, Dec. 15–17, Brown U., Providence, R.I.

American Association for the Advancement of Science, Annual Meeting, Dec. 26–31, Atlanta, Ga.

American Institute of Electrical Engineers, Winter General Meeting, Jan. 30–Feb. 3, 1956, Hotel Statler, New York.

American Institute of Physics, 25th Anniversary Celebration, Jan. 30–Feb. 4, 1956, Hotel New Yorker, New York.

Optical Society of America, Feb. 1, 1956, (Massachusetts Institute of Technology, Cambridge, Mass.).

Acoustical Society of America, Feb. 1, 1956, (57 E. 55 St., New York 22).

Optical Society of America, Apr. 5–7, 1956, Bellevue-Stratford, Philadelphia, Pa.

79th Semiannual Convention of the SMPTE, including Equipment Exhibit, Apr. 29–May 4, 1956, Hotel Statler, New York.

80th Semiannual Convention of the SMPTE, Oct. 7–12, 1956, Ambassador Hotel, Los Angeles.

Optical Society of America, Oct. 18–20, 1956, Lake Placid Club, Essex Co., N.Y.

Optical Society of America, Mar. 7–9, 1957, Hotel Statler, New York.

81st Semiannual Convention of the SMPTE, Apr. 28–May 3, 1957, Shoreham Hotel, Washington, D.C.

82nd Semiannual Convention of the SMPTE, including Equipment Exhibit, Oct. 6–11, 1957, Hotel Statler, New York.

83rd Semiannual Convention of the SMPTE, April 20–26, 1958, Ambassador Hotel, Los Angeles.

84th Semiannual Convention of the SMPTE, Oct. 19–24, 1958, Sheraton-Cadillac, Detroit.

85th Semiannual Convention of the SMPTE, May 3–8, 1959, Fontainebleau, Miami Beach, Fla.

86th Semiannual Convention of the SMPTE, including Equipment Exhibit, Oct. 5–10, 1959, Hotel Statler, New York.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections, Subsections and Chapters, and of the Committee Chairmen and Members were published in the April Journal.

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